Summary Report on Phosphorus Removal

Research Report No. 83

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Research Program for the Abatement of Municipal Pollution
Under Provisions of the Canada-Ontario Agreement
on Great Lakes Water Quality

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These RESEARCH REPORTS describe the results of investigations funded under the Research Program for the Abatement of Municipal Pollution within the provisions of the Canada-Ontario Agreement on Great Lakes Water Quality. They provide a central source of information on the studies carried out in this program through in-house projects by both Environment Canada and the Ontario Ministry of Environment, and contracts with municipalities, research institutions and industrial organizations.

Enquiries pertaining to the Canada-Ontario Agreement RESEARCH PROGRAM should be directed to -

Wastewater Technology Centre
Canada Centre for Inland Waters
Environment Canada
O. Box 5050
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ario Ministry of Environment
lution Control Branch
St. Clair Avenue West
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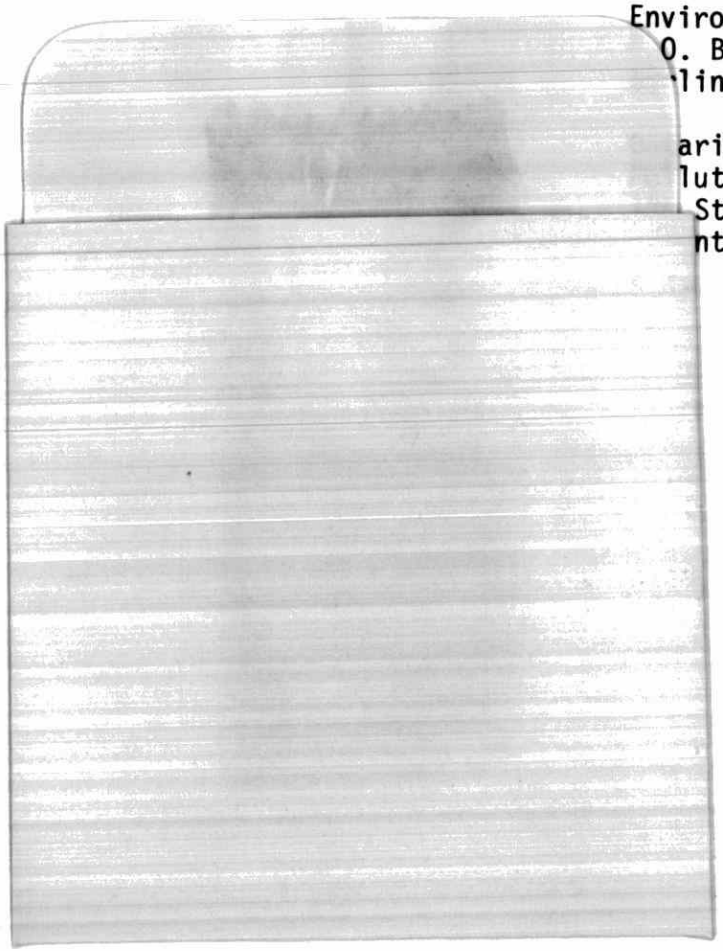

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SEWAGE TREATMENT –

SUMMARY REPORT ON PHOSPHORUS REMOVAL

by

J.D. Archer
Ontario Ministry of the Environment

RESEARCH PROGRAM FOR THE ABATEMENT
OF MUNICIPAL POLLUTION WITHIN THE
PROVISIONS OF THE CANADA-ONTARIO
AGREEMENT ON GREAT LAKES WATER QUALITY

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ABSTRACT

This report covers the findings of the phosphorus removal studies carried out on wastewater treatment plants under the Canada-Ontario Agreement on Great Lakes Water Quality. Phosphorus removal can be achieved at any existing wastewater treatment plant with the addition of iron salts, aluminum salts or lime. Since essentially any of these three chemicals can adequately remove phosphorus at a wastewater treatment plant, the purpose of the treatability studies described in this report was to determine which chemical would most economically remove the phosphorus to the required level, yet be totally compatible with the existing treatment process.

Information was collected on the phosphorus removal facilities installed at wastewater treatment plants, to compare the actual performance of these facilities with the predictions that were made from treatability studies. The two-stage treatment study (jar and full-scale testing) was found to be the most reliable method of selecting the appropriate chemical and dosage rate. Operational problems, and capital and operating costs are presented and discussed.

RÉSUMÉ

Le présent rapport traite des résultats de certaines études sur la déphosphatation dans des installations traitant les eaux usées; cette recherche a été effectuée dans le cadre de l'Accord Canada-Ontario sur la qualité des eaux des Grands lacs. On peut réaliser la déphosphatation dans n'importe quelle situation simplement en ajoutant de la chaux ou bien des sels de fer ou d'aluminium. Puisque ces substances sont toutes efficaces, les études avaient pour but de déterminer la plus économique, qui convienne en même temps au procédé d'épuration utilisé.

On a recueilli des données sur les systèmes de déphosphatation de diverses usines d'épuration afin de comparer leur rendement réel avec les prévisions découlant de l'étude de leur potentiel de traitement. Le traitement en deux étapes (en laboratoire et à l'échelle industrielle) s'est révélé la méthode la plus fiable pour déterminer la substance appropriée et son dosage. Nous examinons enfin les problèmes d'exploitation ainsi que les coûts d'investissement et d'exploitation.

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SUMMARY

The Government of Ontario has, through the Ministry of the Environment, completed the first phase of its nutrient removal program with the installation of phosphorus removal facilities at selected wastewater treatment facilities in the Great Lakes and Ottawa River Basins. The success of this program could only be achieved through the cooperation of the Federal and Provincial Governments under the terms set forth in the Canada-Ontario Agreement on Great Lakes Water Quality (COA). Funds provided through the Canada-Ontario Agreement allowed research studies to be carried out by Federal and Provincial governments, as well as by consulting engineers and private groups. Treatability studies were carried out at most wastewater treatment plants by consulting firms on behalf of municipalities. Technical expertise was provided by Provincial and Federal personnel when requested.

This report covers the findings of all the treatability studies carried out on wastewater treatment plants in the Lower Great Lakes Basin, as well as information collected from the permanent operation of all phosphorus removal facilities at sewage treatment plants having an implementation date of December 31, 1973. It shows that phosphorus removal can be achieved at any existing wastewater treatment facility. Municipalities with phosphorus removal equipment have consistently achieved effluent criteria placed upon them by the Ministry of the Environment.

The findings of this report strongly indicate that the two phase treatability study (jar and full-scale testing) is the best and most reliable method for purposes of chemical selection and process compatibility, although permanent phosphorus removal facilities are achieving effluent standards with dosage rates less than those predicted by the treatability studies. This is primarily due to the climatization of the sludges and stabilization of plant operation after continuous chemical feed is undertaken.

1. INTRODUCTION

The International Joint Commission report completed in 1969, following a six-year study of pollution in the Lower Great Lakes, recommended that phosphorus discharges from all sources in the drainage basin be reduced to the lowest practical level. Subsequently, the Government of Canada, under the terms of Canada Water Act (1970), enacted a policy calling for a reductions in the phosphorus content of detergents, to a limit (by weight as P_2O_5) of 20% by August 1970 and 5% by December 31, 1972. Concurrently, the Province of Ontario announced a policy requiring the installation of phosphorus removal facilities at municipal and institutional wastewater treatment plants located not only in the Lower Great Lakes but also in the Ottawa River system, parts of the Upper Great Lakes and throughout inland recreational areas.

Initially, the policy required a minimum removal of 80% of the phosphorus from the wastewater plant influent with higher levels of removal to be determined by further studies of the receiving waters. This criterion was subsequently superceded in the Lower Great Lakes by the signing, in April, 1972, of the Canada-United States Agreement on Great Lakes Water Quality [1], which called for an effluent object of 1 mg/L total phosphorus.

Permanent phosphorus removal facilities were to be operational by December 31, 1973 in the most critically affected areas of the Province, i.e., the complete Lake Erie basin, parts of the Lake Huron and Ottawa River basins as well as certain recreational areas of the Lake Ontario, Lake Huron and Ottawa River watersheds. A December 31, 1975 deadline was established for the remainder of the Lake Ontario basin and a portion of the Ottawa River basin. As well, phosphorus removal facilities could be requested in other areas of the Province where problems were found or where recreational potential might exist. Figure 1 illustrates the phosphorus removal schedule compliance dates discussed above. A report entitled "Summary Report on the Phosphorus Removal Program" provides a complete review of the Phosphorus Removal Program in the Province of Ontario [2].

As a prelude to the Canada-United States Agreement, the Governments of Canada and Ontario, in August 1971, signed an Agreement [3] to

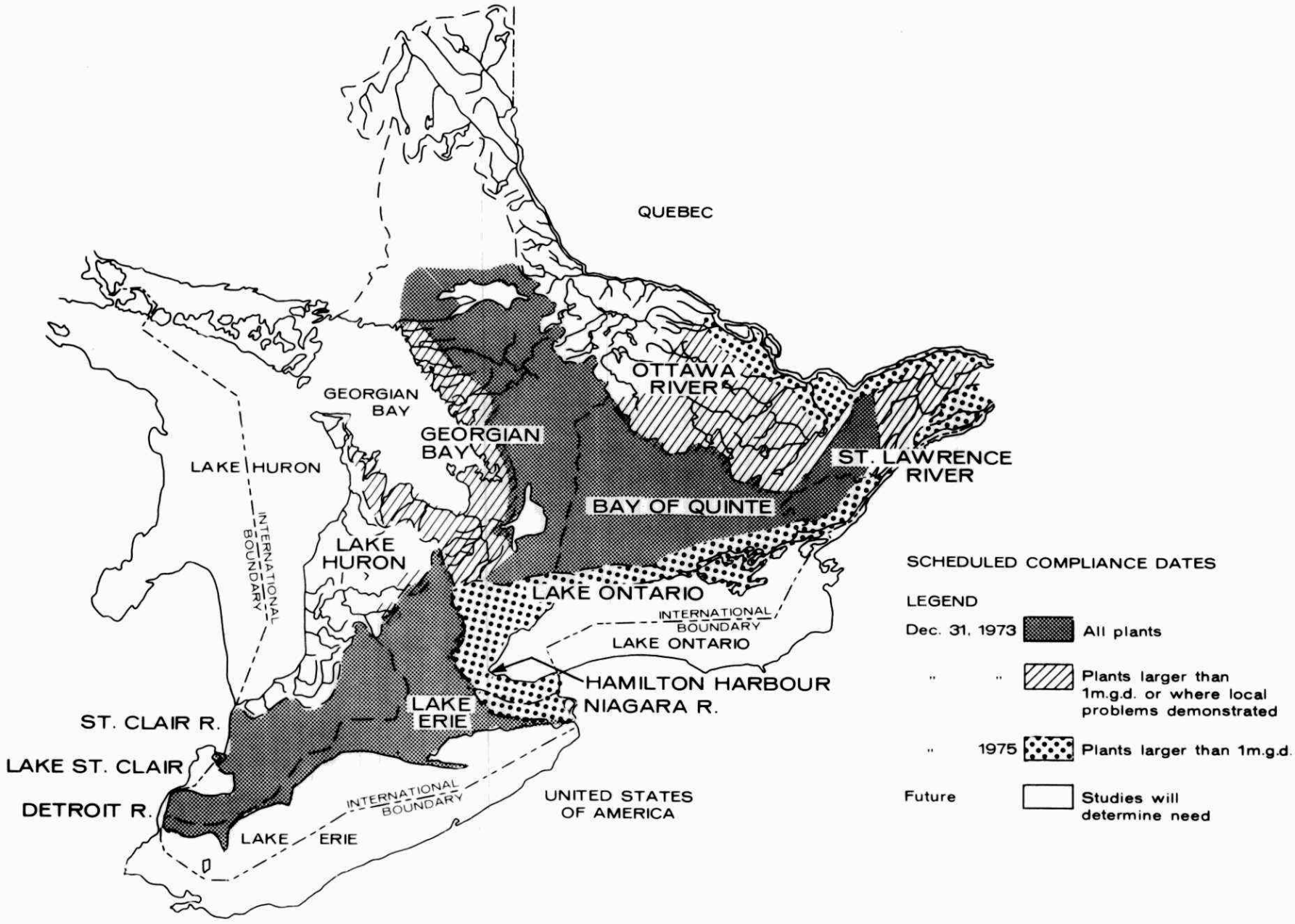


FIGURE 1. PROVINCE OF ONTARIO PHOSPHORUS REMOVAL PROGRAM

implement and accelerate programs of pollution control in the Lower Great Lakes to meet the recommendations of the IJC. The Agreement secured funding for a $250 million capital works program aimed at upgrading sewage collection systems and treatment works, including the installation of phosphorus removal equipment at an estimated cost of $15 million. An additional $6 million over the five-year term of the Agreement was provided for related research and studies. Phosphorus removal technology and treatability studies were to be given top priority in the research program. During the period covered by the Agreement, some $480 million was spent by Federal, Provincial and Municipal governments for the construction of sewage plants, trunk sewers and collection systems.

The $6 million research fund was to be jointly shared and administered by the Governments of Canada and Ontario. While some of the research was to be carried out by the research sections of the two governments, many important projects were funded through contract arrangements with the private sector.

In order to implement phosphorus removal policy, a treatability studies program was developed to aid in the selection of a coagulant best suited for phosphorus removal at any individual plant, as well as to determine the effects of chemical addition on the existing treatment process, including sludge treatment and disposal methods. Municipalities in the Lower Great Lakes basin were reimbursed money spent on the treatability studies. Expenditures eligible for reimbursement and the procedure for requesting such were outlined in the Ministry publication entitled "Guidelines for Initiating Treatability Studies for Phosphorus Removal" [4]. For municipalities not eligible for reimbursement, the Ontario Ministry of the Environment assisted by providing equipment and/or technical expertise wherever possible.

In addition, a document entitled "Province of Ontario Phosphorus Removal Questionnaire, Operational Data and Cost Summary" was prepared and sent out in April, 1976, to the operating authorities of all wastewater treatment plants required to have phosphorus removal facilities installed and operational by December 31, 1973. A total of 64 municipal wastewater treatment plants with permanent phosphorus removal installations were surveyed.

1.1 Purpose

The purpose of this report is to summarize the data presented in the treatability study reports regarding the number of plants tested, phosphorus concentrations, chemical dosages, sludge production and testing costs. Also, phosphorus concentrations and chemical dosages required to achieve effective phosphorus removal were to be studied to determine whether they could be related by valid mathematical models. Variations in the chemical dosages between jar tests and full-scale tests are discussed in section 2 of this report.

Information on the permanent operation of the phosphorus removal facilities was collected through questionnaires sent to the operating authorities of all wastewater treatment plants with a December 31, 1973 implementation deadline. Information on chemical selection and dosages, sludge production and disposal, as well as capital and operating costs, are presented in section 3 of this report.

2. TREATABILITY STUDIES

The treatability studies program was a two-phase testing procedure consisting of preliminary jar testing, followed by full-scale plant testing. Using plant samples, jar tests were performed to determine the chemical and dosage which would most economically and consistently provide the degree of phosphorus removal required. The full-scale tests, performed on all or part of the actual plant flows, were used to confirm the findings of the jar tests as well as to determine the compatibility of the added chemical with the operational characteristics of the plant.

Pre-design study procedures were outlined in a Ministry publication entitled "Guidelines for Conducting Treatability Studies for Phosphorus Removal at Wastewater Treatment Plants", April 1972 [4].

2.1 Jar and Full-Scale Testing

2.1.1 Chemicals used

The data provided in this report were taken from the jar and full-scale tests conducted at the wastewater treatment plants in the Lower Great Lakes Drainage basin. Essentially there are three basic chemical types which can be used to control phosphorus in wastewater streams. These are:

1) aluminum salts,
2) iron salts,
3) lime.

Although there are many forms of iron and aluminum salts which can effectively remove phosphorus, only two, namely aluminum sulphate and ferric chloride were tested. In some instances, however, other forms of iron salts were used for full scale studies in order to verify that they could remove phosphorus equally as well. The following is a list of chemicals utilized in the treatability studies.

Chemical Name		Concentrations Expressed as
aluminum sulphate	$Al_2(SO_4)_3 \cdot 14H_2O$	$Al_2(SO_4)_3 \cdot 14H_2O$
ferric chloride	$FeCl_3$	Fe^{+++}
hydrated lime	$Ca(OH)_2$	Ca(OH)2

In addition to the above chemicals, the below noted pickle liquors can be used for phosphorus removal in most secondary type treatment plants.

Chemical Name		Concentrations Expressed as
ferrous sulphate	$FeSO_4$	Fe^{+++}
ferrous chloride	$FeCl_2$	Fe^{+++}

2.1.2 Jar testing

Jar testing studies carried out used ferric chloride, aluminum sulphate and lime. Probability curves for each chemical tested were plotted and used for full-scale testing chemical selection. Chemical selection was based on the least expensive chemical which, as shown on the probability curves, could achieve the required removal 80% of the time. In certain instances where layout or design criteria of the wastewater treatment plant did not permit, full-scale chemical selection was based on other criteria.

Appendix I lists the chemicals tested along with the estimated dosage requirements to either the primary and/or secondary section (where applicable) of the wastewater treatment plant in order to achieve the required degree of phosphorus removal. Jar testing cost and pertinent comments with regard to the studies are also shown in Appendix I.

Table 1 shows, for both primary and secondary type treatment plants, the number of plants tested, and the estimated chemical dosage required to meet effluent objectives.

Under the terms of the treatment studies, the consultant or authority conducting the jar tests was required to submit a report for review and approval by Provincial and Federal authorities before proceeding to the full-scale studies.

2.1.3 Full-scale testing

Full-scale studies were conducted at the majority of wastewater treatment plants in the Lower Great Lakes basin. Based on the recommendations of the jar testing studies, full-scale studies were carried out under on-site conditions at the wastewater treatment facilities involved. These studies, in most instances, were of six weeks duration for primary treatment plants, and of eight weeks duration for secondary treatment

TABLE 1. JAR TESTING CHEMICAL DOSAGE SUMMARY

	CHEMICAL	NUMBER OF PLANTS DOSED WITH EACH CHEMICAL	REQUIRED DOSAGE TO MEET OBJECTIVES RANGE (mg/L)	AVERAGE (mg/L)
Primary Plants	Alum	16	50-300	125
	Ferric chloride	16	5-40	16
	Lime	15	100-600	214
Conventional Secondary Plants				
- addition to raw sewage	Alum	52	25-550	179
	Ferric chloride	52	4-120	40
	Lime	47	65-600	292
- addition to secondary section	Alum	59	5-330	105
	Ferric chloride	58	4-90	21

Note: Values shown throughout report are:

Alum	as $Al_2(SO_4)_3 \cdot 14H_2O$
Ferric Chloride	as Fe^{+++}
Hydrated Lime	as $Ca(OH)_2$

plants. Chemical compatibility, dosage points, mixing, and settling characteristics, as well as overall plant operation and sludge production were observed and recorded. Effluent phosphorus concentrations were closely monitored. The consultants in charge of the full-scale studies were required to submit a report for review and approval by Provincial and Federal authorities. The recommendations put forth in these reports were used for the design, construction, and operation of the permanent phosphorus removal facilities.

Appendix II shows, for each plant where full-scale studies were carried out, the chemical tested, the point of addition, and the dosage required to achieve the necessary phosphorus removal. Also shown is the cost associated with the full-scale testing along with any comments pertinent to the study itself.

Table 2 shows, for both primary and secondary type sewage treatment systems, the chemical dosage, the range of dosage required to meet objectives and the average dosage for each chemical type.

2.1.4 Comparison of jar and full-scale testing chemical requirements

The jar tests were used to estimate the optimum chemical dosage required to control phosphorus discharges and provide a 1 mg/L total phosphorus effluent. The full-scale tests were performed on each plant to verify the chemical selection and compatibility with the existing treatment process. For the majority of the plants tested, the full-scale test's chemical requirements varied from the estimations of the jar tests. (See Appendices I and II.)

Full-scale testing using alum and lime additions at primary plants indicated that slightly less chemical was required than estimated by the jar test studies. Similar full-scale studies utilizing ferric chloride did not indicate any significant differences from the chemical requirements estimated from the jar tests. However, since there were only 11 primary plants for which treatability studies were carried out, no consistent trends in chemical dosage requirements between jar and full-scale testing could be established. When alum or ferric chloride was added to the secondary section of the wastewater treatment plants, consistent reductions in the chemical requirements compared to the jar

TABLE 2. FULL-SCALE TESTING CHEMICAL DOSAGE SUMMARY

	CHEMICAL	NUMBER OF PLANTS DOSED WITH EACH CHEMICAL	REQUIRED DOSAGE TO MEET OBJECTIVES RANGE (mg/L)	AVERAGE (mg/L)
Primary Plants	Alum	4	60-150	102
	Ferric chloride	9	10-25	17
	Lime	1	330	330
Conventional Secondary Plants				
- addition to primary section	Alum	-	-	-
	Ferric chloride	-	-	-
	Lime	3	160-210	180
- addition to secondary section	Alum	20	4-138	65
	Ferric chloride	33	2-125	17
	Lime	-	-	-

Note: Values shown throughout report are:

Alum as $Al_2(SO_4)_3 \cdot 14H_2O$

Ferric Chloride as Fe^{+++}

Hydrated Lime as $Ca(OH)_2$

testing results were evident. This is primarily due to the build-up of the iron or aluminum salts in the sludge. It is also anticipated that, once these plants have phosphorus removal facilities on line and achieve equilibrium with respect to return sludge and possible recirculation of the chemical, the chemical dosage required may be reduced even further.

2.2 Phosphorus Concentrations and Required Chemical Dosages

To fulfill the second purpose of this report, a series of linear regression analyses were plotted to determine if a statistically valid mathematical relationship could be evolved between phosphorus concentrations and dosage rates required to achieve the 1 mg/L total phosphorus effluent criterion. The data used were taken from information obtained during the jar tests. These tests were considered to be the most controlled and uniform. The regression analysis and 95% confidence limit determinations were done using all the results of jar tests conducted at wastewater treatment plants in the Lower Great Lakes.

After fitting a regression line to a set of points it is then necessary to determine how statistically valid the regression line is. The coefficient of multiple determination, r^2, is related to the regression of the X_0's. The actual value for r^2 is related to the regression line, with values of 0.8 to 1.0 generally accepted as indicating a good mathematical model. A value of 8.0 indicates that 80% of observed variations of Y_0 are explained by the regression equation.

The linear regression and 95% confidence bands are shown in Figures 2, 3, and 4. Figure 2 shows linear regression and confidence bands for the dosing of alum, ferric chloride and lime to the raw sewage of primary type sewage treatment plants. Figure 3 shows similar information for the dosing of the same three chemicals to the raw sewage at conventional secondary type plants, while Figure 4 shows the results of dosing and alum and ferric chloride to the secondary section of secondary type treatment plants. The regression lines fitted in Figures 2 to 4 have coefficients of multiple determination (r^2) ranging from 0.048 to 0.462, which are significantly lower than the range of an accepted regression line.

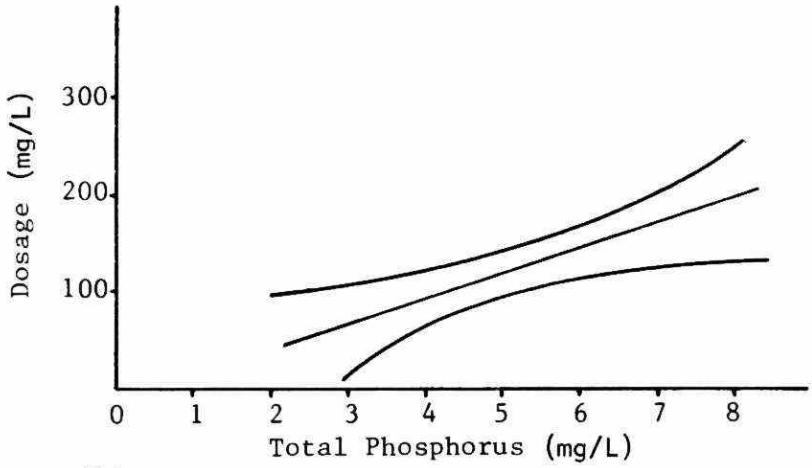
ALUM

$Al_2(SO_4)_3 \cdot 14H_2O$

$r = .67969$

$r^2 = .462$

$N = 12$



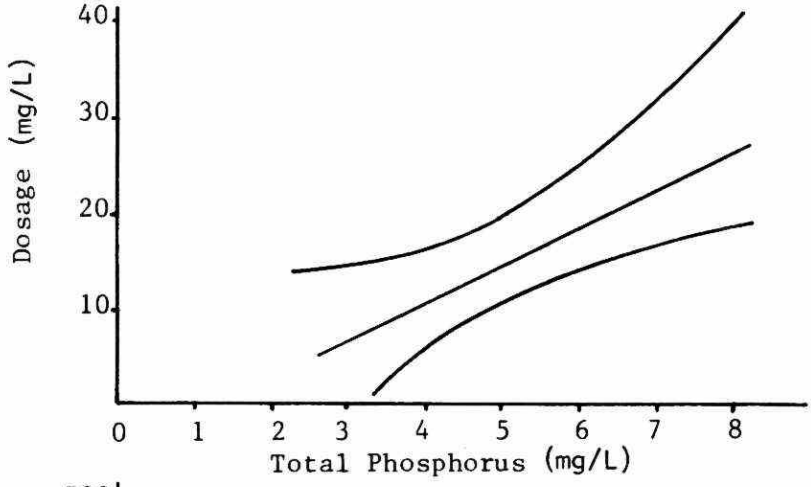
FERRIC CHLORIDE

(Fe^{+++})

$r = .66299$

$r^2 = .439$

$N = 12$



LIME

$(CaCO_2)$

$r = .2194$

$r^2 = .048$

$N = 12$

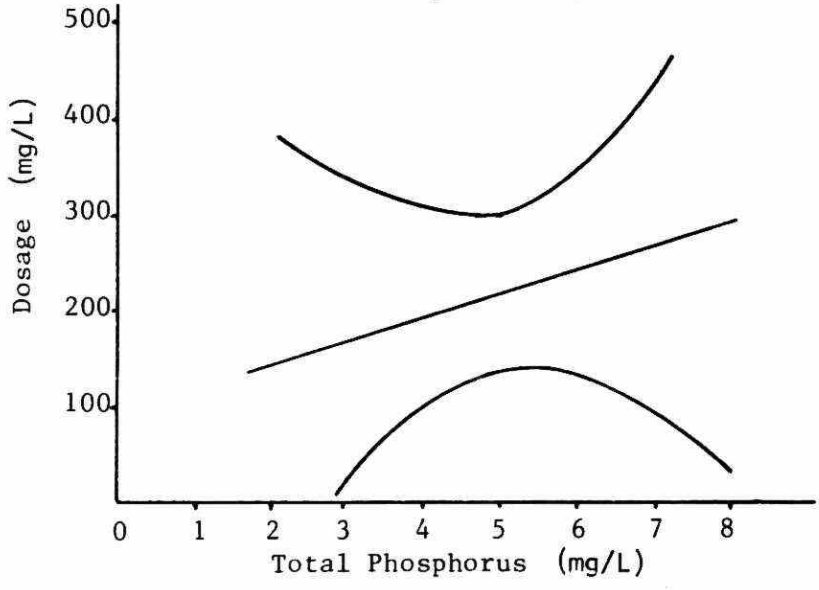


FIGURE 2. LINEAR REGRESSION AND 95% CONFIDENCE BAND FOR CHEMICAL ADDITION TO PRIMARY PLANTS - RAW SEWAGE

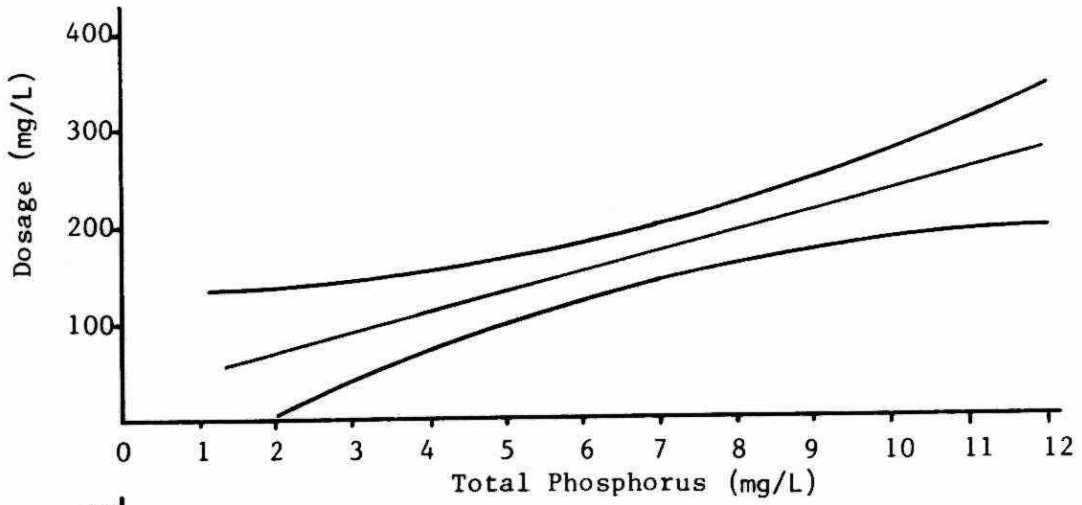
ALUM

$(Al_2(SO_4)_3 \cdot 14H_2O$

$r = .5686$

$r^2 = .323$

$N = 41$

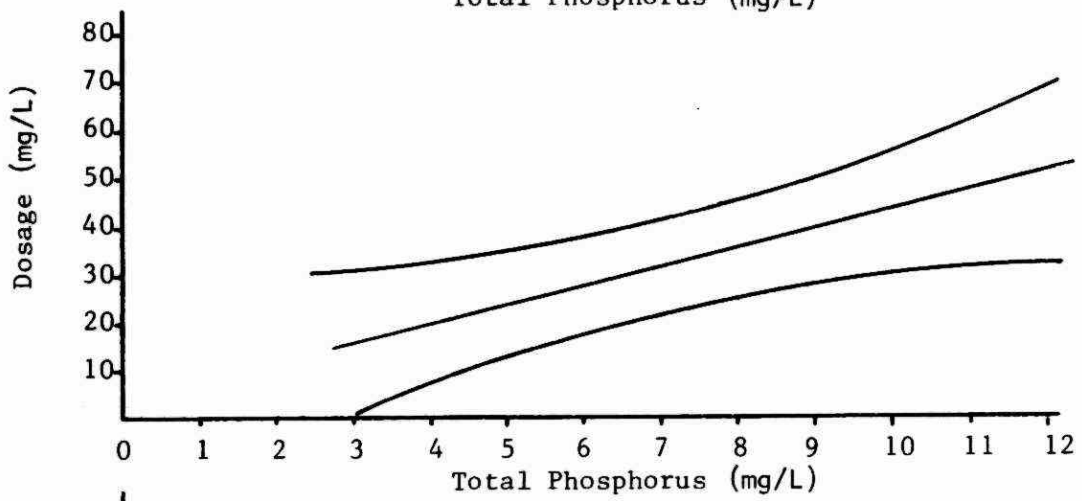


FERRIC CHLORIDE
(Fe^{+++})

$r = .3815$

$r^2 = .146$

$N = 41$



LIME
$(CaCO_2)$

$r = .2235$

$r^2 = .05$

$N = 40$

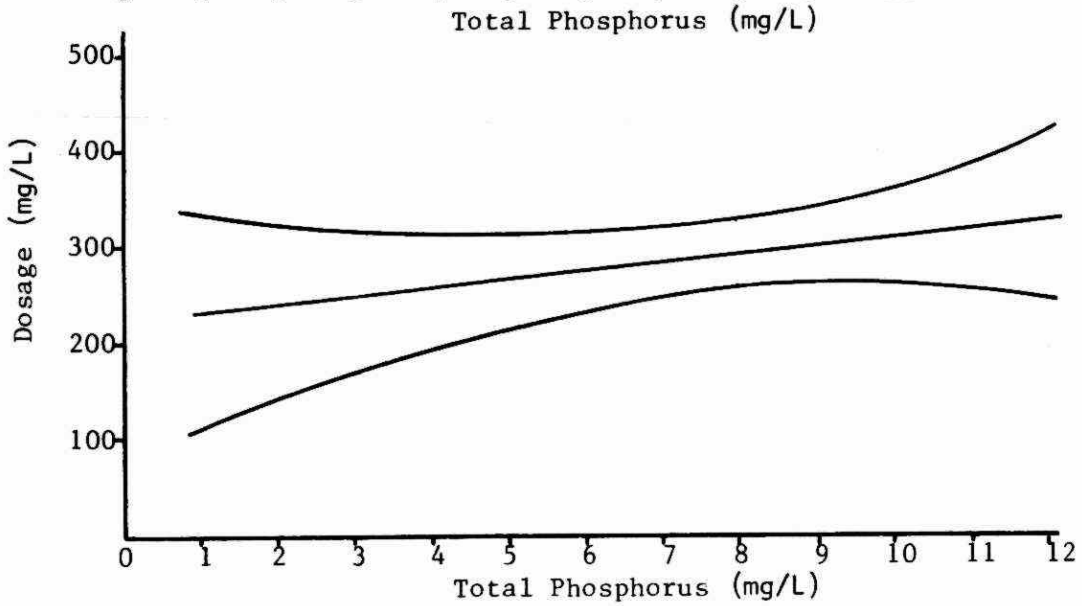


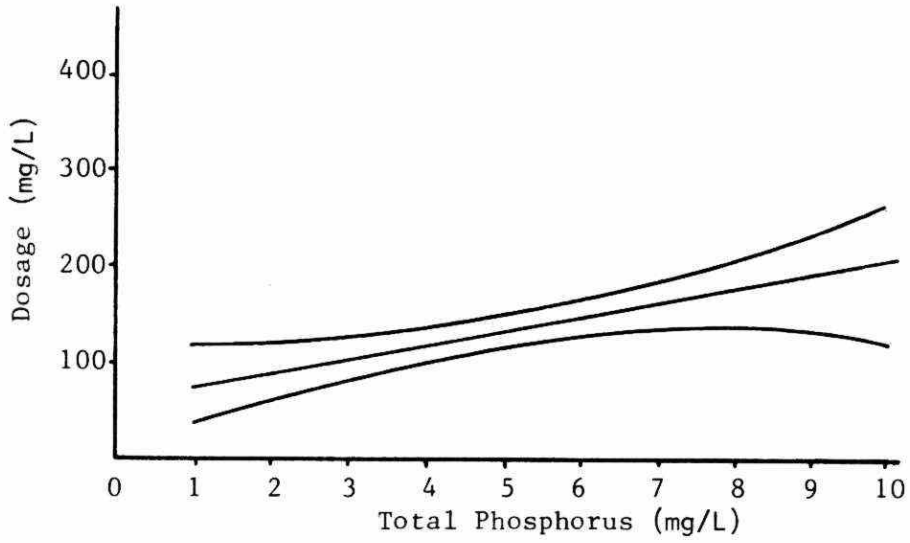
FIGURE 3. LINEAR REGRESSION AND 95% CONFIDENCE BAND FOR CHEMICAL ADDITION TO SECONDARY PLANTS - RAW SEWAGE

ALUM
$(Al_2(SO_4)_3 \cdot 14H_2O$

$r = .3608$

$r^2 = .130$

$N = 49$



FERRIC CHLORIDE
(Fe^{+++})

$r = .4221$

$r^2 = .178$

$N = 47$

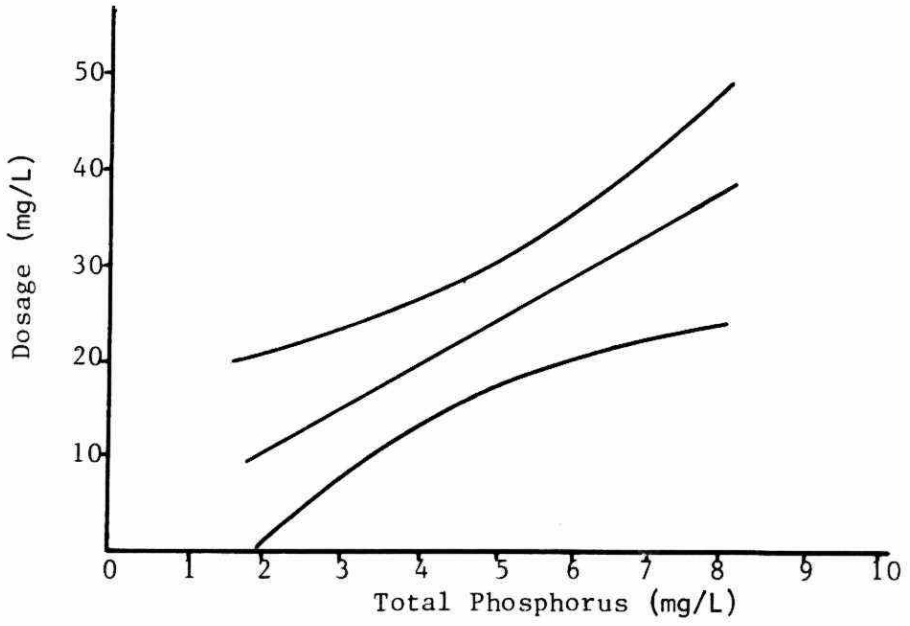


FIGURE 4. LINEAR REGRESSION AND 95% CONFIDENCE BAND FOR CHEMICAL ADDITION TO SECONDARY PLANTS - FINAL EFFLUENT

For Figures where the chemical was added to the raw sewage, the data is presented as chemical dosages versus the average value of total influent phosphorus concentrations. In Figure 4, where the chemicals were added to the secondary section of the plants, the data is presented as chemical dosages versus the average value of total effluent phosphorus prior to chemical addition.

From these findings it is concluded that, although general trends do exist (i.e. higher phosphorus concentrations require larger chemical dosages), linear regression does not provide a good mathematical model to describe the relationship between phosphorus concentrations and the required chemical dosages to achieve 1 mg/L in the effluent.

2.3 SLudge Production

The addition of a chemical precipitant to a waste stream for the purposes of phosphorus removal results in an increased sludge production at the wastewater treatment plant. At the 23 plants tested for which reliable values could be established, the maximum increase in sludge production was 100%, with the average increase in sludge production being about 35%. In 21 plants the additional cost of sludge handling was calculated. The maximum cost increase was estimated at $12.60 per million imperial gallons of sewage treated, while the average value for the 21 plants was estimated at $3.27 per million gallons of sewage treated. This topic is discussed further in the Section 3.

2.4 Treatability Studies Cost

The total cost of the treatability studies program was approximately $1.5 million. Table 3 shows expenditures for the jar and full-scale testing in conjunction with the drainage basin and implementation date.

Only a few treatability studies, such as those from mechanical plants, were carried out for the lagoon type wastewater treatment systems. Testing was done to determine phosphorus concentrations. The lagoon was then dosed and the contents discharged to the receiving stream or lake. As a result, in the majority of cases, the only data available for lagoon installations was the chemical used.

TABLE 3. TREATABILITY STUDIES COSTS

DRAINAGE BASIN	TOTAL JAR TESTS COSTS	TOTAL FULL-SCALE TESTS COSTS	TOTAL COSTS
	$	$	$
Lake Erie 1973	96,628.70	560,324.64	656,953.34
Lake Ontario 1973	1,722.03	16,361.91	18,083.94
Lake Ontario 1975	235,530.96	518,065.09	753,596.05
Total Costs	333,881.69	1,094,751.64	1,428,633.33

2.5 Chemical Selection For Permanent Operation

A survey was conducted immediately prior to the 1973 and 1975 implementation dates to determine the number of treatment facilities utilizing the various types of phosphorus removal chemicals. In the Lower Great Lakes, 78 municipal and institutional treatment facilities were required to have phosphorus removal facilities operational by the December 1973 deadline. An additional 33 plants located in the Upper Great Lakes and Ottawa River Systems were also required to be on line by the end of 1973.

Fifty plants in the Lower Great Lakes and seven in the Upper Great Lakes and Ottawa River Systems were required to have phosphorus removal facilities operational by December 31, 1975.

Table 4 indicates for each basin the number and type of plants using each chemical at the time when permanent operation commenced. Plants failing to meet the implementation deadline are not shown in this summary table. It should be pointed out, however, that municipalities are free to change chemicals for economical and operational advantages providing an acceptable chemical is used.

2.6 Conclusions and Recommendations

1) The data collected from the treatability studies reports regarding phosphorus removal is summarized in Tables 1 to 4, with detailed information included in Appendix I and Appendix II.

TABLE 4. CHEMICAL SELECTION SUMMARY

DRAINAGE BASIN AND IMPLEMENTATION DATE	TYPE OF PLANT	NUMBER OF PLANTS USING EACH CHEMICAL						TOTAL NUMBER OF PLANTS	TOTAL HYDRAULIC CAPACITY
		ALUM	FERRIC CHLORIDE	LIME	OTHER*	NONE** REQUIRED	UNDETERMINED		
Lake Erie 1973	Primary	1	5	0	0	0	0	6	37.66 mgd
	Conventional Secondary	10	17	3	2	0	0	32	131.03 mgd
	Modified Secondary	2	2	0	0	0	0	4	0.48 mgd
	Lagoons	18	0	0	0	1	1	20	578 acres
Basin Total		31	24	3	2	1	1	62	---
Lake Ontario 1973	Primary	0	1	0	0	0	0	1	12.0 mgd
	Conventional Secondary	2	0	0	0	1	0	3	1.48 mgd
	Modified Secondary	0	0	0	0	0	1	1	0.15 mgd
	Lagoons	5	0	0	0	1	0	6	232.6 acres
Basin Total		7	1	0	0	2	1	11	---

* Includes ferrous salts
** Chemical addition not required at this time.
Compliance with Ministry objectives presently being met.

TABLE 4. (CONT'D)

DRAINAGE BASIN AND IMPLEMENTATION DATE	TYPE OF PLANT	NUMBER OF PLANTS USING EACH CHEMICAL						TOTAL NUMBER OF PLANTS	TOTAL HYDRAULIC CAPACITY
		ALUM	FERRIC CHLORIDE	LIME	OTHER*	NONE** REQUIRED	UNDETERMINED		
Lake Ontario 1975	Primary	4	6	0	0	0	1	11	62.05 mgd
	Conventional Secondary	9	19	1	0	3	1	33	442.0 mgd
	Modified Secondary	0	5	0	0	0	0	5	33.12 mgd
	Lagoons	0	0	0	0	0	0	0	---
Basin Total		13	30	1	0	3	2	49	---
Province Total		51	55	4	2	6	4	122	---

* Includes ferrous salts
** Chemical addition not required at this time.
Compliance with Ministry objectives presently being met.

2) A total of $1.43 million was paid to municipalities for treatabiity studies conducted at wastewater treatment plants located in the Lower Great Lakes basin.

3) Statistical analysis utilizing linear regressions did not provide a valid mathematical model to describe the relationships between either influent or effluent phosphorus concentrations and chemical dosage required to meet the objectives.

4) In a comparison between jar and full-scale results, where chemicals were added to the primary section of a wastewater treatment plant, no consistent reductions or increases in chemical dosages necessary to meet Ministry objectives were observed. However, in a similar comparison for addition to the secondary section of plants, a lower chemical concentration than shown by the jar studies proved adequate for removing the phosphorus during the full-scale studies. It is anticipated that further reduction in chemical requirements will occur as the conventional secondary plants reach equilibrium after permanent facilities for phosphorus removal are installed.

5) From the study, it was found that liquid feed systems were much more adaptable to a sewage system than the dry storage lime feed systems. At primary treatment plants the most commonly used point of chemical addition was the aerated grit channels (when available). For secondary treatment facilities, the aeration tank effluent (for ferric and aluminum solutions) and aeration tank influent (for ferrous solutions) were the most commonly used points of addition for the chemical feed systems.

6) Based on the findings of the treatability studies, the two-phased testing procedure is the best way of determining chemical and dosage selection for purposes of phosphorus removal at wastewater treatment plants.

3 PERMANENT OPERATION

In April 1976 a document entitled "Province of Ontario Phosphorus Removal Questionnaire, Operational Data and Cost Summary" was prepared and sent out to the operating authorities of all wastewater treatment plants required to have phosphorus removal facilities installed and operational by December 31, 1973.

A total of 64 municipal wastewater treatment plants with permanent phosphorus removal installations were surveyed. The purpose of the survey was to obtain plant operational data and cost information arising from phosphorus removal implementation.

For plants in the Lower Great Lakes basin requiring phosphorus removal by December 31, 1973, a total phosphorus effluent concentration not exceeding 1 mg/L is required, while plants in the Upper Great Lakes are required to remove 80% of the incoming total phosphorus. When the raw sewage concentration is weak (less than 5.0 mg/L total phosphorus) plants in the Upper Lakes and Ottawa River basins need only to remove the phosphorus to a level of 1 mg/L.

This section summarizes the information obtained through the questionnaire sent to the operating authorities of the wastewater treatment plants. Chemical, sludge and cost information are summarized and presented in Appendix III.

3.1 Chemical and Dosage Information

3.1.1 Chemicals used

There are three basic types of chemicals used for phosphorus removal. These are aluminum salts, iron salts and lime. Both aluminum and iron salts are used primarily in an aqueous form while lime, although added to the sewage stream in a slurry, is shipped in dry bulk form.

Although many forms of aluminum salts can be used, only aluminum sulphate at this time is available in sufficient quantities to be marketable for purposes of phosphorus removal. Iron salts, on the other hand, are commercially available in many forms, for example, ferric chloride, ferric sulphate, ferrous chloride and ferrous sulphate. Since it is the iron portion that reacts with the soluble reactive orthophosphate to form a precipitate, all of these forms of iron salts can be readily used for

phosphorus removal. One word of caution, however, should be expressed. Iron salts must be in the ferric form before a complete reaction with soluble orthophosphate can take place. Therefore, ferrous salts cannot be used in primary treatment plants. They can, and have been, successfully used in secondary treatment plants where retention time and adequate oxygen supplies are available to convert the ferrous ion to the ferric ion.

Table 5 shows the number of plants using the various forms of aluminum salts, iron salts and lime for purposes of phosphorus removal. At the time of the survey 64% of the sewage treatment plants were using iron salts for phosphorus removal while 25% and 6% of the plants were utilizing alum and lime, respectively.

TABLE 5. PERMANENT OPERATION CHEMICAL USE SUMMARY

Chemical	Number of Plants Using the Chemical	Percent of Total
Aluminum Sulphate $Al_2(SO_4)_3 \cdot 14H_2O$	16	25%
Ferrous Sulphate $FeSO_4$	13	20%
Ferric Sulphate $Fe_2(SO_4)_3$	0	0%
Ferrous Chloride $FeCl_2$	1	2%
Ferric Chloride $FeCl_3$	27	42%
Lime $Ca(OH)_2$	4	6%
Not Required*	3	5%
Total	64	100%

* Note: three plants met the 1 mg/L phosphorus effluent requirement without the use of chemicals.

It should be noted that three of the 64 plants surveyed were using no chemicals at all. This is because the effluents discharge from these wastewater treatment plants were meeting Ministry criteria without chemical addition.

3.1.2 Chemical dosage

Treatability studies were carried out at most wastewater treatment plants requiring phosphorus removal to determine chemical selection, dosage rate, point of addition and chemical compatibility with the sewage treatment process. It was generally found that dosage rates differed from plant to plant because of the variations of sewage strength and composition. In most instances, however, both aluminum salts and iron salts effectively removed the phosphorus from the sewage stream. In certain instances where iron or aluminum salts appeared not to work, lime often proved successful. Although treatability studies were carried out primarily with the three basic chemical types, it has been shown since that different forms of iron salts will effectively remove the phosphorus and are compatible with most sewage treatment processes.

In most instances at primary treatment plants, chemicals were added to the aerated grit channel. Where there was no aerated grit removal tank available or accessible, the iron and aluminum salts were usually dosed at the raw sewage lift pumps. The chemical dosing point for both these chemicals was similar. It must be stressed again that ferrous salts cannot be used in primary treatment plants because the iron ion must be in the ferric form in order that proper phosphorus removal can take place. Primary facilities do not have the oxygen or adequate retention time to convert the ferrous ion to the ferric ion.

In secondary treatment plants there were two basic points of application. For aluminum and iron salts (ferric form) the point of addition found most compatible was in the aeration tank effluent immediately prior to its discharge to the final clarifiers. However, a few plants utilizing ferric salts add at the beginning of the aeration tank. When the plant uses iron salts in the ferrous form, the chemical addition point must be at the beginning of the aeration tank. Lime addition in secondary type sewage treament plants must take place prior to the primary clarifier so that the lime sludge is removed in the primary clarifier. Because of the elevation in pH resulting from the addition of lime to remove phosphorus, lime cannot be used in the secondary section of the sewage treatment plant without detrimental effects to the biomass of the activated sludge process.

Table 6 shows the number of plants utilizing aluminum salts, iron salts and lime, as well as the dosage range and mean dosage required to effectively control the phosphorus. Generally speaking, higher chemical dosages were required at primary plants than at secondary to control the phosphorus. This, of course, is primarily due to a higher concentration of solids and phosphorus in the primary section of a sewage treatment plant. From Table 6 it can be seen that an average of approximately 100 mg/L of alum or approximately 16 mg/L of iron as Fe^{+++} was required to effectively control phosphorus in a primary plant. Lime dosages were approximately 185 mg/L.

In the secondary section of sewage treatment plants, alum dosages required averaged about 60 mg/L, while iron salts, again as Fe^{+++}, were in the vicinity of 10 to 11 mg/L. For comparative purposes the values predicted from jar and full-scale testing at primary and secondary plants are shown in Tables 1 and 2.

3.1.3 Problems related to chemical usage

In most instances aluminum and iron salts posed very little problem to the operation of treatment facilities. Chemical compatibility with the raw sewage did not present a problem at wastewater treatment plants throughout the province. Where liquid feed systems are utilized, however, one must ensure that during the winter months the chemicals are kept at a temperature within the suppliers specifications in order to prevent crystalization or freezing.

Lime, on the other hand, has generally resulted in operational difficulties wherever it has been used. Mixing and feeding facilities have caused considerable maintenance problems and high manpower requirements. The use of lime has also caused mechanical failure of equipment in certain sewage treatment plants. These problems can be overcome by detailed maintenance and repair programs.

One important sewage treatment function which may be affected by the use of chemicals for phosphorus removal is the disposal of sewage sludges. The Ministry of the Environment is preparing guidelines for the utilization of liquid sewage sludge on farm land based on the content of ammonia and heavy metals other than iron. The Ministry is

TABLE 6. PERMANENT OPERATION CHEMICAL DOSAGE SUMMARY

	CHEMICAL	NUMBER OF PLANTS DOSED WITH EACH CHEMICAL	CHEMICAL DOSAGE	
			RANGE (mg/L)	MEAN (mg/L)
Primary Treatment				
- addition to raw sewage	Lime	3	167-200	185
	Alum	1	100	100
	Iron salts (as Fe^{+++})	9	6-30	16
Secondary Treatment				
- addition to raw sewage	Lime	2	40-100	70
	Alum	0	-	-
	Iron salts (as Fe^{+++})	0	-	-
- addition to secondary section	Lime	0	-	-
	Alum	15	30-150	65
	Iron salts (as Fe^{+++})	32	2-30	11

also undertaking a detailed program to assess the heavy metal concentrations in sewage sludges across the province and evaluate the effects of chemicals used for phosphorus removal. Specific guidelines for heavy metal concentrations in chemicals used for phosphorus removal have not been set by the Ministry although they may be necessary in the future. Chemicals presently being utilized for phosphorus removal are evaluated based on their effect on the sewage treatment process within the plant itself.

3.2 Sludge Production and Disposal

3.2.1 Sludge Production

Since the implementation of chemical precipitation at wastewater plants requiring phosphorus removal, the resulting sludge production and utlimate disposal have been areas of major concern. Understandably, when a chemical is added to precipitate dissolved material in a waste stream, the amount of sludge produced has to be greater than before chemical precipitation. The question arises, however, as to how much more.

In a Canada-Ontario Agreement report "Survey of Ontario Sludge Disposal Practices", soon to be published, it is stated that at primary plants with chemical precipitation there was a 70% increase by volume (113% by weight) in the amount of sludge produced. Similarily, for secondary plants a 14% increase by volume (34% by weight) was observed. The information used in computation of the above noted values was collected primarily from municipalities with a December 1973 implementation deadline for phosphorus removal.

Data collected for this report showed similar values for additional sludge volumes resulting from phosphorus removal. The information supplied was checked where possible and unreliable data disregarded. However, for the 40 secondary and eight primary treatment plants for which reliable data was collected, the increase in sludge volumes resulting from chemical precipitation was 76% for primary and 28% for secondary type plants. These figures may change when sufficient information from plants with the December 31, 1975 deadline becomes available.

An attempt to calculate the increase in dry solids was not carried out because of lack of necessary data from most plants.

3.2.2 Sludge disposal

Information collected from the municipalities surveyed is summarized below:

Disposal Method	Number of Plants	% of Total Sludge by Volume
Farmland	42	65
Landfill	7	10
Incineration	4	22
Other Methods	17	3

Note: Six municipalities reported more than one method of sludge disposal.

3.3. Capital, Chemical and Operational Costs

3.3.1 Capital costs

One of the most important aspects of phosphorus removal is the costs associated with equipment purchase and installation. In the questionnaire, the municipalities were asked what the cost was for the purchase and installation of the phosphorus removal equipment. Phosphorus removal equipment was defined as chemical storage, feed pumps, transfer pipes, and associated mechanical and electrical appurtenances. Consultants costs and labour costs were included where applicable.

In general, the phosphorus removal capital costs for a typical 1 mgd wastewater treatment plant utilizing a fibreglass reinforced tank with heating elements, two variable speed chemical metering pumps (one for standby), the necessary mechanical apparatus including chemical feedlines which are heat traced, electrical equipment to ensure proper chemical feed metering and heating of tanks and feedlines when necessary, and lastly, associated structural cost which is essentially a foundation for the storage tank, can be broken down as follows:

	Costs (1975 dollars)
Tank (6000 gallons)	7,000
Pumps (2)	2,500
Mechanical	1,000
Electrical	1,000
Structural	1,000
Engineering contingency	1,500
	14,000

These costs could not be directly applied to plants larger than 1 mgd. As the plant size increases the cost per million gallons of design capacity decreases. Figure 5 shows the average costs for the wastewater treatment plants surveyed.

The total capital costs for phosphorus removal equipment of the 64 plants was just under two million dollars. Apppendix III gives a detailed summary of the capital costs for each wastewater treatment plant.

It should be pointed out also that the capital costs do not include any associated costs resulting from the implementation of phosphorus removal. Plant enlargement or the expansion of sludge handling facilities are not included in the capital cost.

3.3.2 Chemical costs

Prices for phosphorus removal chemicals in the Province of Ontario usually vary with the quantity of chemicals required and the distance from the source of supply. Since the liquid feed systems are designed to handle either aluminum or iron salts, municipalities are free to switch chemicals depending on availability and economics. Chemical costs during the summer of 1976 for the municipalities surveyed were:

Alum	\$70.95 - \$83.74 (per ton of dry alum)
Iron salts	0.12 - 0.23 (per pound Fe)
Lime	34.50 - 44.35 (per ton of bulk hydrated lime)

These prices were slightly higher for 1977. To obtain a more representative feeling for the chemical cost associated with phosphorus removal, the values were converted to a cost per million gallons of sewage treated. These costs ranged from \$2.48 to \$76.88 per million gallons of sewage treated with the average being approximately \$23. Appendix III lists the chemical cost per million gallons of sewage treated for each wastewater treatment plant that was surveyed.

3.3.3 Operational costs

Operating costs for phosphorus removal equipment include such things as routine maintenance (including parts), electricity required to run the pumps and to heat the tanks during the winter months if required,

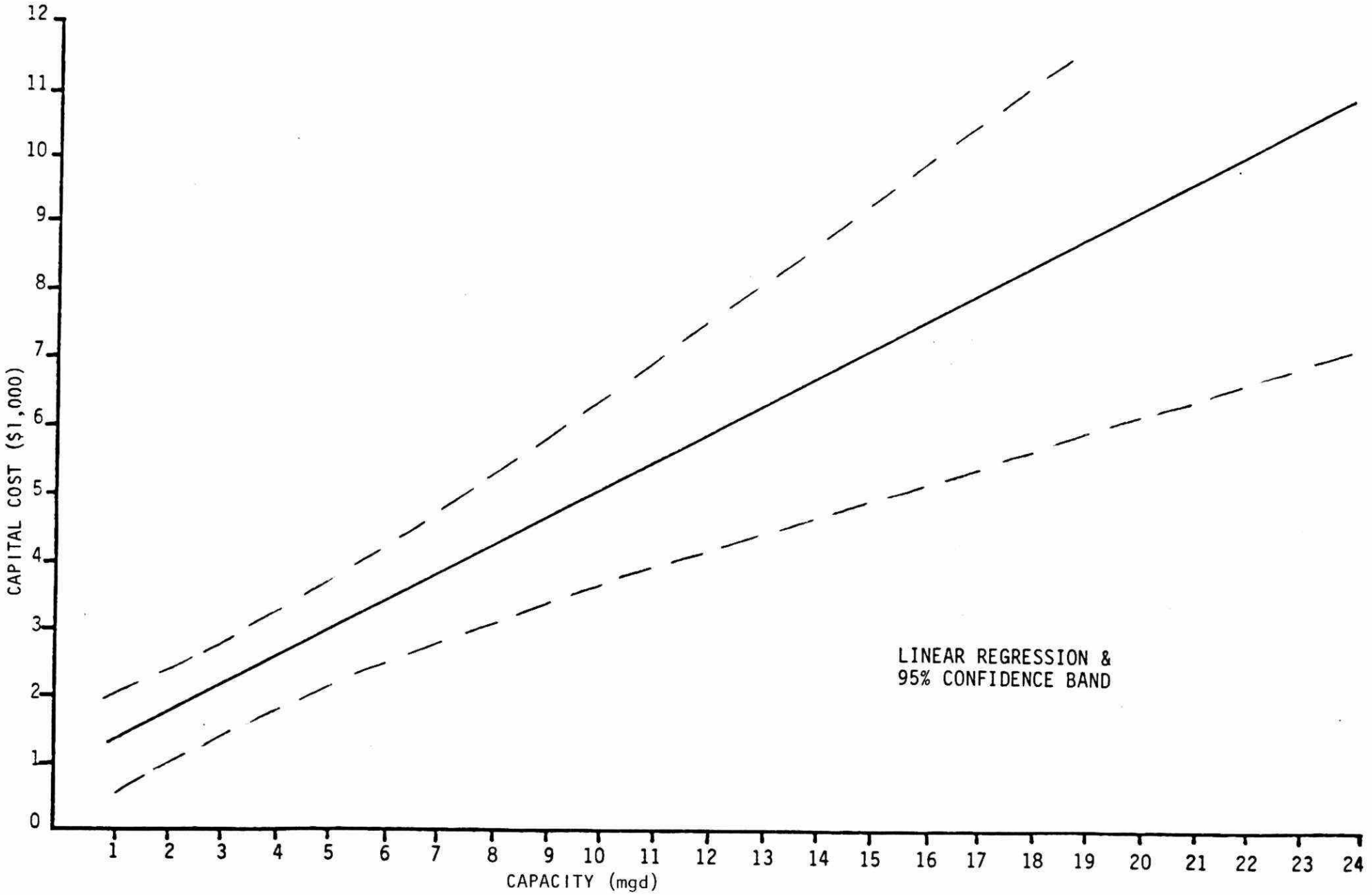


FIGURE 5. PHOSPHORUS REMOVAL EQUIPMENT CAPITAL COSTS (1975 dollars)

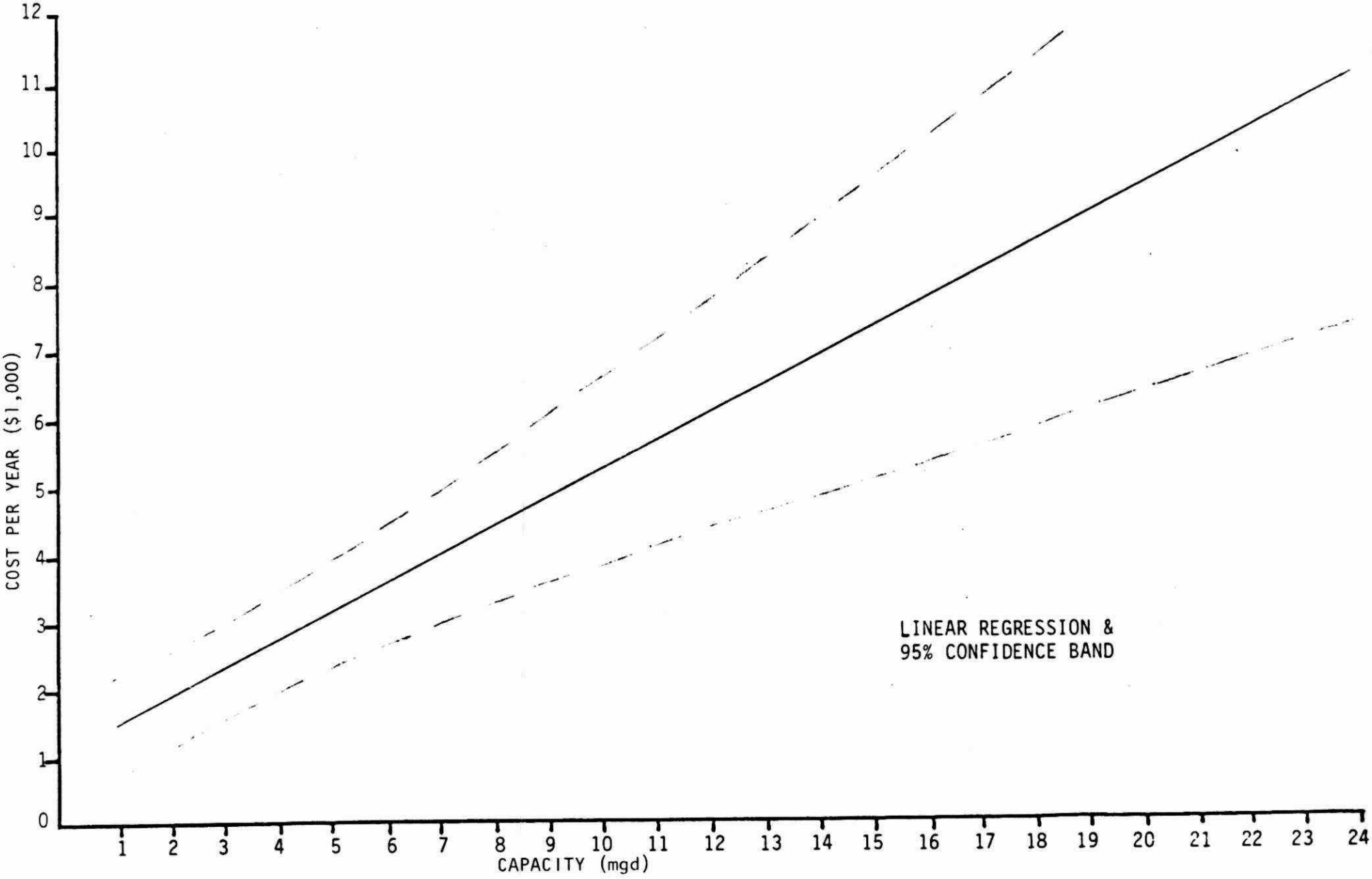


FIGURE 6. PHOSPHORUS REMOVAL OPERATIONAL COSTS* (1975 dollars)

*Excludes Chemical Costs

water where make-up water is necessary, and the manpower associated with all the above functions. Figure 6 shows the operating expenses on a cost per design capacity basis. Although the costs varied greatly, the operating cost for a 1 mgd plant is about $1600, and $5,400 for a 10 mgd plant. It should be noted that operating costs reported herein do not include chemical costs.

3.4 Conclusions and Recommendations

1) Chemical utilization for purposes of phosphorus removal can be implemented at any existing wastewater treatment plant with little or no operational difficulty.
2) The use of liquid feed systems (i.e. iron or aluminum salts) proved to be much more flexible than that of the dry type system (lime).
3) At the time the data was collected iron salts were being used at approximately 64% of the plants surveyed while alum and lime were being used at 25% and 6%, respectively. The remaining three plants were meeting the effluent criteria without chemical addition.
4) The average chemical cost per million gallons of sewage treated was $23.
5) Sludge volumes increased an average of 78% at primary plants and 28% at secondary plants with the implementation of phosphorus removal.
6) Capital cost for the installation of a liquid feed phosphorus removal system at a typical 1.0 mgd wastewater treatment plant was reported to be about $14,000.
7) Operational costs averaged about $380 for each million gallons of design capacity. Operational costs include maintenance, electricity and makeup water, as well as the manpower associated with the above functions.

REFERENCES

1. Canada-United States Agreement on Great Lakes Water Quality (April, 1972).
2. Ontario Ministry of the Environment, Municipal and Private Section, Pollution Control Branch, "Summary Report on the Phosphorus Removal Program" (April, 1976).
3. Canada-Ontario Agreement on the Lower Great Lakes Water Quality (August, 1971)
4. Ontario Ministry of the Environment, Sanitary Engineering Branch, "Guidelines for Conducting Treatability Studies for Phosphorus Removal at Wastewater Treatment Plants" (April, 1972).
5. International Joint Commission - Canada and United States, "Pollution of Lake Erie, Lake Ontario, and the International Section of the St. Lawrence River", Volumes 1, 2, and 3 (1969).

ACKNOWLEDGEMENTS

The Ministry of the Environment would like to extend its appreciation to all of the municipal employees, provincial employees and consulting engineers who, through sampling programs and operating records, made this report possible. A special thanks is extended to the Waterloo Co-op students, J.F. Leppard, A.R. Martin, E.P. Charlebois, and M. Demirli, for their assistance in the compilation and preparation of this report.

APPENDIX I

TREATABILITY STUDIES REPORTS SUMMARY

PHASE 1 - JAR TESTING

APPENDIX I

TREATABILITY STUDIES REPORTS SUMMARY PHASE 1 - JAR TESTING

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	RECEIVING BASIN IMPLEMENTATION DATE	CHEMICALS TESTED	CHEMICAL DOSAGE REQUIREMENTS (mg/L)		JAR TESTING COST ($)	COMMENTS
			PRIMARY ADDITION	SECONDARY ADDITION		
Acton Step Aeration 0.62	Lake Ontario 1975	Alum Ferric chloride Lime	360 33 300	165 26 -	6049.90	Recommend ferric chloride to secondary section
Ajax-Duffin Creek Conv. Secondary 1.25	Lake Ontario 1975	Alum Ferric chloride Lime	130 15 285	58 9 -	6237.75	Recommend lime to primary section and ferric chloride to secondary section
Amherstburg Primary 1.0	Lake Erie 1973	Alum Ferric chloride Lime	150 20 125	- - -	6749.00	Recommend lime for phase II; lime not acceptable during canning season; ferric chloride found to be satisfactory
Arthur Lagoon 10 Acres	Lake Erie 1973	Alum	-	-	0	
Alymer Lagoon 72 Acres	Lake Erie 1973	Alum	-	-	0	
Belleville Conv. Secondary 8.0	Lake Ontario 1975	Alum Ferric chloride Lime	125 14 250	60 12 -	355.45	Recommend alum to Secondary section

APPENDIX I (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	RECEIVING BASIN IMPLEMENTATION DATE	CHEMICALS TESTED	CHEMICAL DOSAGE REQUIREMENTS (mg/L)		JAR TESTING COST ($)	COMMENTS
			PRIMARY ADDITION	SECONDARY ADDITION		
Bicroft Lagoon 10 Acres	Lake Ontario 1973	-	-	-	0	P levels less than 1 mg/L without chemical addition
Bolton Conv. Secondary 0.5	Lake Ontario 1975	Alum Ferric chloride Lime	275 32 732	149 24 -	5672.34	Recommend alum to secondary section
Bowmanville Trickling Filter 0.5	Lake Ontario 1975	Alum Ferric chloride Lime	176 25 399	99 16 -	5987.64	Recommend ferric chloride to secondary section
Brantford Conv. Secondary 12.5	Lake Erie 1973	Alum Ferric chloride Lime	200 33 500	125 20 -	1155.86	Recommend ferric chloride to secondary section
Brockville Primary 3.75	Lake Ontario 1975	Alum Ferric chloride Lime	70 13.5 150	- - -	6655.03	Recommend alum
Burlington-Skyway Extended Aeration 6.0	Lake Ontario 1975	Lime Ferric chloride Alum & Percol 292	175 25 150 & 0.5	- 35 75& .05	10,400.00	

APPENDIX I (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	RECEIVING BASIN IMPLEMENTATION DATE	CHEMICALS TESTED	CHEMICAL DOSAGE REQUIREMENTS (mg/L) PRIMARY ADDITION	SECONDARY ADDITION	JAR TESTING COST ($)	COMMENTS
Cont'd) Burlington-Skway	Lake Ontario 1975	Ferrous chloride & Lime & Percol 292	30 & 100 & 0.5	- -		
		Ferrous chloride & Sodium hydroxide & Percol 292	45 & 30 & 0.5	- -		
		Pickle liquor & Ferrous chloride & Lime & Percol 292	30 100 0.5	- - -		
Burlington-Drury Lane Conv. Secondary 2.5	Lake Ontario 1975	Alum	121	60.5	6612.45	Recommend ferric chloride to secondary section
		Ferric chloride	19	9.5		
		Lime	320	-		
Caledonia Conv. Secondary 0.5	Lake Erie 1973	Alum	440	165	6849.79	Recommend lime to raw sewage
		Ferric chloride	45	14		
		Lime	80	-		

APPENDIX I (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	RECEIVING BASIN IMPLEMENTATION DATE	CHEMICALS TESTED	CHEMICAL DOSAGE REQUIREMENTS (mg/L) PRIMARY ADDITION	CHEMICAL DOSAGE REQUIREMENTS (mg/L) SECONDARY ADDITION	JAR TESTING COST ($)	COMMENTS
Campbellford Conv. Secondary 0.75	Lake Ontario 1973	Alum Ferric chloride Lime	25 5 140	0 0 -	729.94	No full-scale test required as phosphorus levels less than 1 mg/L without chemical addition
Cayuga Oxidation Ditch 0.20	Lake Erie 1973	Alum Ferric chloride	- -	130 20	410.51	Recommend ferric chloride to secondary section
Chatham Conv. Secondary 4.5	Lake Erie 1973	Ferrous sulphate	40	-	0	COA report
Cobourg Conv. Secondary 3.53	Lake Ontario 1975	Alum Ferric chloride Lime	116 20 273	22 4 -	6605.03	Recommend ferric chloride to secondary section
Cornwall Primary 8.0	Lake Ontario 1975	Alum Ferric chloride Lime	50 10 200	- - -	3616.04	Recommend alum
Delhi Conv. Secondary 0.5	Lake Erie 1973	Alum Ferric chloride Lime	130 16.5 310	83 13.5 -	5634.46	Recommend ferric chloride to secondary section
Dundalk Lagoon 16 Acres	Lake Erie 1973	Alum	-	-	0	No report done

APPENDIX I (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	RECEIVING BASIN IMPLEMENTATION DATE	CHEMICALS TESTED	CHEMICAL DOSAGE REQUIREMENTS (mg/L)		JAR TESTING COST ($)	COMMENTS
			PRIMARY ADDITION	SECONDARY ADDITION		
Dundas Conv. Secondary 2.0	Lake Ontario 1975	Alum Ferric chloride Lime	150 30 275	50 10 150	5500.00	Recommend lime in primary section
Dunnville Conv. Secondary 1.7	Lake Erie 1973	Aluminum sulphate Ferric chloride Pickle liquor N.R. Alum	- - - -	5 9 10 44	4661.28	Recommend pickle liquor with ferric chloride backup
Dutton Lagoon 10 Acres	Lake Erie 1973	Alum	-	-	0	No report done
Elmira Conv. Secondary 0.68	Lake Erie 1973	Alum Ferric chloride Lime	250 30 400	125 17	887.25	Recommend ferric chloride to secondary section
Elora Extended Aeration 0.1 Conv. Secondary	Lake Erie 1973	Alum Ferric chloride	- -	115 26	335.47	Recommend ferric chloride to secondary section
Essex Lagoon 58 Acres	Lake Erie 1973	Alum	-	-	0	No report done
Fergus Conv. Secondary 1.1	Lake Erie 1973	Alum Ferric chloride Lime	140 22 175	75 15 -	746.12	Recommend ferric chloride to secondary section

APPENDIX I (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	RECEIVING BASIN IMPLEMENTATION DATE	CHEMICALS TESTED	CHEMICAL DOSAGE REQUIREMENTS (mg/L)		JAR TESTING COST ($)	COMMENTS
			PRIMARY ADDITION	SECONDARY ADDITION		
Fort Erie Primary 1.8	Lake Ontario 1975	Alum Ferric chloride Lime	88 9 213	- - -	5777.58	Recommend ferric chloride
Fort Erie -Crystal Beach Conv. Secondary 0.85	Lake Erie 1973	Alum Ferric chloride Lime	50 8 180	25 6 -	5662.05	Recommend alum to secondary section
Frankford Conv. Secondary 0.30	Lake Ontario 1973	-	-	-	0	No report done Plant constructed after implementation date
Galt Conv. Secondary 8.5	Lake Erie 1973	Alum Ferric chloride Lime	400 45 550	130 25 -	1899.64	Recommend alum to secondary section; ferric chloride used in full-scale studies
Georgetown Conv. Secondary 1.5	Lake Ontario 1975	Alum Ferric chloride	99 13	110 10.5	6219.93	Recommend ferric chloride to secondary section
Grand Valley Oxidation Ditch 0.13	Lake Erie 1973	Alum Ferric chloride	- -	110 30	264.42	Recommend alum to secondary section
Guelph Conv. Secondary 10.0	Lake Erie 1973	Alum Ferric chloride Lime	75 45 300	- - -	619.20	Tests on secondary addition not completed; recommend alum to secondary section

APPENDIX I (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	RECEIVING BASIN IMPLEMENTATION DATE	CHEMICALS TESTED	CHEMICAL DOSAGE REQUIREMENTS (mg/L) PRIMARY ADDITION	CHEMICAL DOSAGE REQUIREMENTS (mg/L) SECONDARY ADDITION	JAR TESTING COST ($)	COMMENTS
Hagersville Conv. Secondary 0.20	Lake Erie 1973	Alum	125	75	0	Recommend alum to secondary section
		Ferric chloride	25	18		
		Lime	65	-		
Hamilton Conv. Secondary 60.0	Lake Ontario 1975	Alum	90	-	4700.00	Phosphorus levels less than 1 mg/L without chemical addition
		Ferric chloride	20	-		
Hespeler Conv. Secondary 1.6	Lake Erie 1973	Alum	-	175	176.50	Recommend ferric chloride to secondary section
		Ferric chloride	-	18		
Ingersoll Conv. Secondary 2.25	Lake Erie 1973	-	-	-	0	No jar testing
Jarvis Lagoon 14 Acres	Lake Erie 1973	Alum	-	-	0	No report done
Kingston Primary 13.5	Lake Ontario 1975	Alum	100	-	7996.05	Recommend ferric chloride
		Ferric chloride	15	-		
		Lime	300	-		
Kingston Twp., Conv. Secondary 2.2	Lake Ontario 1975	Alum	90	50	2211.55	Recommend ferric chloride to secondary section
		Ferric chloride	14	10		
		Lime	300	-		

APPENDIX I (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	RECEIVING BASIN IMPLEMENTATION DATE	CHEMICALS TESTED	CHEMICAL DOSAGE REQUIREMENTS (mg/L)		JAR TESTING COST ($)	COMMENTS
			PRIMARY ADDITION	SECONDARY ADDITION		
Kingsville Lagoon 43 Acres	Lake Erie 1973	Alum	175	-	800.00	
Kitchener Conv. Secondary 13.5	Lake Erie 1973	Alum Ferric chloride Lime	300 52 500	105 22 -	1940.37	Recommend alum to secondary section
Lakefield Lagoon 24 Acres	Lake Ontario 1973	Alum	-	-	0	No report done
Leamington Primary 2.0	Lake Erie 1973	Ferric chloride Lime	15 150	- -	3779.86	
Lindsay Lagoon 111 Acres	Lake Ontario 1973	Alum Ferric chloride	150 38	- -	318.85	Recommend alum
London-Adelaide Conv. Secondary 2.0	Lake Erie 1973	Alum Ferric chloride Lime	275 75 175	275 90 275	4748.17	Recommend lime to primary section
London-Greenway Conv. Secondary 18.3	Lake Erie 1973	Alum Ferric chloride Lime	205 116 460	45 9 -	12,003.60	Recommend ferric chloride to secondary section

APPENDIX I (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	RECEIVING BASIN IMPLEMENTATION DATE	CHEMICALS TESTED	CHEMICAL DOSAGE REQUIREMENTS (mg/L)		JAR TESTING COST ($)	COMMENTS
			PRIMARY ADDITION	SECONDARY ADDITION		
London-Oxford Conv. Secondary 1.2	Lake Erie 1973	Alum Ferric chloride lime	175 90 225	175 90 275	4153.26	Recommend lime to primary section
London-Pottersburg Conv. Secondary 4.0	Lake Erie 1973	Alum Ferric chloride Lime	225 75 225	175 75 175	3974.88	Recommend lime to primary section
London-Vauxhall Conv. Secondary 3.5	Lake Erie 1973	Alum Ferric chloride Lime	275 90 225	275 75 275	4294.17	Recommend lime to primary section
Madoc Lagoon 30 Acres	Lake Ontario 1973	Alum	-	-	0	No report done
Markham-John Street Conv. Secondary 0.75	Lake Ontario 1975	Alum Ferric chloride Lime	275 35 399	165 28 -	6232.70	Recommend ferric chloride to secondary section
Markham-Unionville Secondary & Lagoon 0.4	Lake Ontario 1975	Alum Ferric chloride Lime	330 30 399	143 22 -	6437.29	Recommend ferric chloride to secondary section
Markham-Old Plant	Lake Ontario 1975	-	-	-	0	No report done

APPENDIX I (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	RECEIVING BASIN IMPLEMENTATION DATE	CHEMICALS TESTED	CHEMICAL DOSAGE REQUIREMENTS (mg/L)		JAR TESTING COST ($)	COMMENTS
			PRIMARY ADDITION	SECONDARY ADDITION		
Milton Conv. Secondary 1.0 plus Tertiary Clarifier	Lake Ontario 1975	Alum Lime	- -	- -	4060.00	Recommend lime to tertiary clarifier @ 150 mg/L
Mississauga-Clarkson Extended Aeration 24.0	Lake Ontario 1975	Alum Ferric chloride	- -	77 14	5516.27	Recommend ferric chloride to secondary section
Mississauga-Lakeview Conv. Secondary 37.5	Lake Ontario 1975	Alum Ferric chloride Lime	170 24 250	63 10 -	6570.13	Recommend ferric chloride to secondary section
Mitchell Lagoon 67 Acres	Lake Erie 1973	Alum	-	-	0	
Moore Twp.-Corunna Conv. Secondary 0.32	Lake Erie 1973	Alum & Lime Ferric chloride & Lime	- -	330 & 115 38 & 65	347.88	Recommend ferric chloride & lime to secondary section
Napanee Primary 1.5	Lake Ontario 1975	Alum Ferric chloride Lime	150 12 200	- - -	3852.21	No recommendation made
New Hamburg Lagoon 27.5 Acres	Lake Erie 1973	Alum	-	-	0	No report done

APPENDIX I (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	RECEIVING BASIN IMPLEMENTATION DATE	CHEMICALS TESTED	CHEMICAL DOSAGE REQUIREMENTS (mg/L)		JAR TESTING COST ($)	COMMENTS
			PRIMARY ADDITION	SECONDARY ADDITION		
Niagara Falls - Stamford Primary 10.0	Lake Ontario 1975	Alum Ferric chloride Lime	90 13 250	- - -	5862.30	Recommend ferric chloride
Norwich Lagoon 15 Acres	Lake Erie 1973	Alum	-	-	0	No report done
Norwood Oxidation Ditch 0.15	Lake Ontario 1973	-	-	-	0	No report done Plant constructed after implementation date
Oakville-East End Conv. Secondary 2.0	Lake Ontario 1975	Alum Ferric chloride Lime	99 18.5 200	88 17 -	6500.43	Recommend ferric chloride to secondary section
Oakville-West End Conv. Secondary 6.5	Lake Ontario 1975	Alum Ferric chloride Lime	150 25 250	100 10 -	4505.54	Recommend ferric chloride to secondary section
Orangeville Conv. Secondary 0.75	Lake Ontario 1975	Alum Ferric chloride Lime	150 20 175	125 15 -	0	Recommend alum to secondary section
Oshawa-Harmony Creek # 1 Trickling Filter 7.5	Lake Ontario 1975	Alum Ferric chloride Lime	130 13 140	- - -	6005.85	Recommend ferric chloride to secondary section of trickling filter

APPENDIX I (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	RECEIVING BASIN IMPLEMENTATION DATE	CHEMICALS TESTED	CHEMICAL DOSAGE REQUIREMENTS (mg/L)		JAR TESTING COST ($)	COMMENTS
			PRIMARY ADDITION	SECONDARY ADDITION		
Oshawa # 2 Primary 5.0	Lake Ontario 1975	Alum Ferric chloride Lime	150 15 190	- - -	3272.56	Ferric chloride to primary plant with application to secondary section when operational
Paris Extended Aeration 0.5	Lake Erie 1973	Alum Ferric chloride	- -	150 35	367.48	Recommend alum to secondary section
Peterborough Primary 12.0	Lake Ontario 1973	Alum Ferric chloride Lime	150 10 150	- - -	NIL	Recommend ferric chloride
Petrolia Lagoon 32 Acres	Lake Erie 1973	Alum	-	-	0	No report done
Two. of Pickering - Frenchman Bay Conv. Secondary 2.5	Lake Ontario 1975	Alum Ferric chloride	105 17	60 15	5798.75	Recommend alum to secondary section
Port Colborne-West Conv. Secondary 0.9	Lake Ontario 1975	Strong Raw Alum Ferric chloride Lime Final Alum Ferric chloride	- - - - -	110 10 200 33 6.5		Weak sewage to be treated in primary section only with strong sewage going directly to secondary section

APPENDIX I (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	RECEIVING BASIN IMPLEMENTATION DATE	CHEMICALS TESTED	CHEMICAL DOSAGE REQUIREMENTS (mg/L)		JAR TESTING COST ($)	COMMENTS
			PRIMARY ADDITION	SECONDARY ADDITION		
Port Dover Primary 2.09	Lake Erie 1973	Alum	225	-	383.42	Recommend ferric chloride to primary section
		Ferric chloride	40	-		
		Lime	600	-		
Port Hope Conv. Secondary 2.0	Lake Ontario 1975	Alum	175	125	4646.65	Recommend either chemical with multiple points of addition in aeration section
		Ferric chloride	25	20		
Port Perry Lagoon 45 Acres	Lake Ontario 1973	Alum	-	-	0	No report done
Picton Contact Stabilization 1.0	Lake Ontario 1975	Alum	-	125	0	Recommend full-scale testing of both chemicals
		Ferric chloride	-	15		
Point Edward Primary 0.57	Lake Erie 1973	Alum	300	-	0	COA report
		Ferric chloride	25	-		
		Lime	150	-		
Port Colborne-East Conv. Secondary 0.85	Lake Ontario 1975	Alum	-	44	5100.00	Recommend alum in secondary section
		Ferric chloride	-	8		
Port Colborne-West Conv. Secondary 0.9	Lake Ontario 1975	Combined Raw				
		Alum	88	-	10,298.05	Recommend full scale tests to determine possibility of separately treating strong and weak sewage streams
		Ferric chloride	8	-		
		Lime	180	-		

APPENDIX I (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	RECEIVING BASIN IMPLEMENTATION DATE	CHEMICALS TESTED	CHEMICAL DOSAGE REQUIREMENTS (mg/L) PRIMARY ADDITION	SECONDARY ADDITION	JAR TESTING COST ($)	COMMENTS
Port Colborne-West (Cont'd)		Weak Raw				
		Alum	55	-		Dose weak with either alum or ferric chloride
		Ferric chloride	4	-		
		Lime	200	-		Dose strong with ferric chloride
Port Rowan Lagoon 21 Acres	Lake Erie 1973	Alum	-	-	0	No report done
Port Stanley Lagoon 40 Acres	Lake Erie 1973	Alum	-	-	0	No report done
Prescott Primary 1.0	Lake Ontario 1975	Alum	60	-	5649.18	Recommend ferric chloride
		Ferric chloride	5	-		
		Lime	100	-		
Preston Conv. Secondary 3.7	Lake Erie 1973	Alum	450	270	1502.18	Recommend ferric chloride to secondary section
		Ferric chloride	70	33		
		Lime	600	-		
Richmond Hill Conv. Secondary 1.6	Lake Ontario 1975	Alum	82.5	44	6586.62	Recommend ferric chloride to secondary section
		Ferric chloride	12.5	7.5		
		Lime	175	-		
Richmond Hill - North Don Conv. Secondary 1.4	Lake Ontario 1975	Alum	-	55	2511.63	Recommend alum to secondary section
		Ferric chloride	-	12		

APPENDIX I (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	RECEIVING BASIN IMPLEMENTATION DATE	CHEMICALS TESTED	CHEMICAL DOSAGE REQUIREMENTS (mg/L) PRIMARY ADDITION	CHEMICAL DOSAGE REQUIREMENTS (mg/L) SECONDARY ADDITION	JAR TESTING COST ($)	COMMENTS
Ridgetown Lagoon 39.5	Lake Erie 1973	Alum	-	-	0	No report done
Sarnia Primary 8.0	Lake Erie 1973	Ferric chloride	20	-	0	Jar testing done by municipality; other chemicals tested; no data available
Sidney Twp. - Batawa Conv. Secondary 0.12	Lake Ontario 1973	Alum Ferric chloride Lime	70 12 200	30 6 -	673.24	Recommend alum to secondary section
Simcoe Conv. Secondary 2.0	Lake Erie 1973	Alum Ferric chloride Lime	300 50 400	150 28 -	694.29	Recommend alum to secondary section
St. Catherines - Port Dalhousie Primary 9.0	Lake Ontario 1975	Alum Ferric chloride Lime	90 12 225	- - -	5030.79	Recommend ferric chloride
St. Catharines - Port Weller Conv. Secondary 8.2	Lake Ontario 1975	Alum Ferric chloride Lime	99 13 333	55 9 -	6200.00	Recommend alum to secondary section
St. Mary's Conv. Secondary 0.8	Lake Erie 1973	Alum Ferric chloride Lime	250 28 300	140 22 -	496.93	Recommend ferric chloride to secondary section

APPENDIX I (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	RECEIVING BASIN IMPLEMENTATION DATE	CHEMICALS TESTED	CHEMICAL DOSAGE REQUIREMENTS (mg/L) PRIMARY ADDITION	CHEMICAL DOSAGE REQUIREMENTS (mg/L) SECONDARY ADDITION	JAR TESTING COST ($)	COMMENTS
St. Thomas Conv. Secondary 3.6	Lake Erie 1973	Alum & Percol 725	82.5 0.5	132 0.5	5200.00	
		Ferric chloride & Percol 725	24.0 0.5	24.0 -		Recommend alum and percol applied to raw sewage; polymer may not be necessary
		Pickle liquor & Percol 722 Lime	33.8 0.5 90.0	48.0 0.5 -		
Stirling Lagoon 12.6	Lake Ontario 1973	Alum	-	-	0	No report done
Stouffville Conv. Secondary 0.49	Lake Ontario 1975	Alum Ferric chloride Lime	165 20 266	77 13 -	6290.09	Recommend ferric chloride to secondary section
Stratford Tertiary Conv. Secondary 6.0	Lake Erie 1973	Alum Ferric chloride Lime	150 20 100	- - -		Recommend ferric chloride to primary section
Strathroy Lagoon 60 Acres	Lake Erie 1973	Alum	-	-	0	No report done

APPENDIX I (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	RECEIVING BASIN IMPLEMENTATION DATE	CHEMICALS TESTED	CHEMICAL DOSAGE REQUIREMENTS (mg/L) PRIMARY ADDITION	CHEMICAL DOSAGE REQUIREMENTS (mg/L) SECONDARY ADDITION	JAR TESTING COST ($)	COMMENTS
Tavistock Lagoon 30 Acres	Lake Erie 1973	Alum	-	-	0	No report done
Tilbury Lagoon 36 Acres	Lake Erie 1973	Alum Ferric chloride	175 25	- -	786.55	Recommend alum
Tillsonburg Conv. Secondary 1.8	Lake Erie 1973	Alum Ferric chloride Lime	300 50 600	150 37 -	750.94	Recommend alum to secondary section
Trenton Primary 1.0	Lake Ontario 1975	Alum Ferric chloride Lime	100 15 300	- - -	511.30	Recommend ferric chloride
Metro Toronto - Humber Conv. Secondary 75.0	Lake Ontario 1975	Alum Ferric chloride Ferric sulphate Lime	- - - -	5 10.5 10.5 200	1431.25	Recommend ferric chloride to secondary section
Metro Toronto-Main - Highland Creek 180.0	Lake Ontario 1975	Alum Ferric chloride Ferric sulphate Lime	- - - -	154 12 14 300	1430.44	Recommend ferric chloride to secondary section

APPENDIX I (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	RECEIVING BASIN IMPLEMENTATION DATE	CHEMICALS TESTED	CHEMICAL DOSAGE REQUIREMENTS (mg/L)		JAR TESTING COST ($)	COMMENTS
			PRIMARY ADDITION	SECONDARY ADDITION		
Metro Toronto - Highland Creek Conv. Secondary 16.0	Lake Ontario 1975	Alum	-	110	1430.44	Recommend ferric chloride to secondary section
		Ferric chloride	-	17		
		Ferric sulphate	-	19		
		Lime	-	250		
Metro Toronto-North Conv. Secondary 7.5	Lake Ontario 1975	Ferric chloride	-	-	0	No jar test studies done
Vaughan-West Don Conv. Secondary 0.33	Lake Ontario 1975	Alum	550	187	6185.00	Recommend ferric chloride to secondary section
		Ferric chloride	120	20		
		Lime	439	-		
Wallaceburg Conv. Secondary 1.5	Lake Erie 1973	Alum	165	100	2037.31	Recommend lime to primary section
		Ferric chloride	21	22		
		Lime	200	-		
Waterford Lagoon 15 Acres	Lake Erie 1973	Alum	150	-	451.09	Recommend ferric chloride
		Ferric chloride	25	-		
Waterloo Conv. Secondary 6.0	Lake Erie 1973	Alum	170	70	1923.14	Recommend ferric chloride
		Ferric chloride	28	13		
		Lime	325	-		
Welland Conv. Secondary 10.0	Lake Ontario 1975	Alum	75	30	6830.19 (Partial)	Recommend alum to secondary section
		Ferric chloride	13	6		
		Lime	175	-		

APPENDIX I (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	RECEIVING BASIN IMPLEMENTATION DATE	CHEMICALS TESTED	CHEMICAL DOSAGE REQUIREMENTS (mg/L) PRIMARY ADDITION	CHEMICAL DOSAGE REQUIREMENTS (mg/L) SECONDARY ADDITION	JAR TESTING COST ($)	COMMENTS
West Lorne Lagoon 20 Acres	Lake Erie 1973	Alum	-	-	0	
Windsor - Little River Conv. Secondary 4.0	Lake Erie 1973	Alum Lime	150 125	100 -		Recommend alum to raw sewage
Windsor - West End Primary 24.0	Lake Erie 1973	Alum Ferric chloride Lime	100 20 150	- - -	1989.77	Recommend alum with polymer
Windsor - West End Primary 24.0	Lake Erie 1973	Polymer (used with Alum & Ferric chloride)	0.3	-		
Woodstock Conv. Secondary 4.5	Lake Erie 1973	Alum Ferric chloride Lime	193 330 490	165 30 -	6968.47	Recommend ferric chloride in secondary section
Woolwich Twp. - St. Jacobs Conv. Secondary 0.211	Lake Erie 1973	Alum Ferric chloride	- -	50 10	234.10	Recommend alum in secondary section
Westminster Twp. - Lambeth Conv. Secondary 0.25	Lake Erie 1973	Alum Ferric chloride	- -	125 18	749.29	Recommend ferric chloride in secondary section

APPENDIX I (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	RECEIVING BASIN IMPLEMENTATION DATE	CHEMICALS TESTED	CHEMICAL DOSAGE REQUIREMENTS (mg/L)		JAR TESTING COST ($)	COMMENTS
			PRIMARY ADDITION	SECONDARY ADDITION		
Town of Whitby - Corbett Creek Conv. Secondary 3.0	Lake Ontario 1975	Alum Ferric chloride	175-300 25-50	100-150 15-25	3871.60	Dosages based on estimates; recommend delay of phase II report
Town of Whitby - Pringle Creek Conv. Secondary 3.25	Lake Ontario 1975	Alum Ferric chloride Lime	200 20 150	100 14 -	6316.96 (Partial)	Recommend ferric chloride to secondary section

APPENDIX II

TREATABILITY STUDIES REPORTS SUMMARY

PHASE 2 - FULL-SCALE TESTING

APPENDIX II

TREATABILITY STUDIES REPORTS SUMMARY PHASE 2 - FULL-SCALE TESTING

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	CHEMICAL TESTED	RECEIVING BASIN IMPLEMENTATION DATE	POINT OF ADDITION	REQUIRED DOSAGE TO MEET OBJECTIVES (mg/L)	FULL-SCALE TESTING COST ($)	COMMENTS
Acton Step Aeration 0.62	Ferric chloride	Lake Ontario 1975	Aeration Tank Effluent	4.0	11,021.89	No operational problems
Ajax Conv. Secondary 1.25	Lime + Ferric chloride	Lake Ontario 1975	Grit Chamber Aeration Tank Effluent	100 5	39,459.28	Lime and ferric chloride are dosed simultaneously for phosphorus control and to improve plant operation
Amherstburg Primary 1.0 (Lime Test)	Lime	Lake Erie 1973	Grit Chamber Effluent	330	7,860.47	Not effective during canning season
(Ferric Chloride Test)	Ferric chloride + Polymer		Pre-aeration inlet + Pre-aeration inlet	20 + 0.5	14,460.45	Ferric chloride + polymer recommended for permanent facilities
Arthur Lagoon 10 Acres	Alum	Lake Erie 1973	Batch Treatment	-	811.43	
Aylmer Lagoon 72 Acres	Alum	Lake Erie 1973	Batch Treatment	-	872.01	
Belleville Conv. Secondary 8.0	-	Lake Ontario 1975	-	-	0	No full-scale study done

APPENDIX II. (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	CHEMICAL TESTED	RECEIVING BASIN IMPLEMENTATION DATE	POINT OF ADDITION	REQUIRED DOSAGE TO MEET OBJECTIVES (mg/L)	FULL-SCALE TESTING COST ($)	COMMENTS
Bicroft Lagoon 10 Acres	No chemical necessary	Lake Ontario 1973	-	-	0	No full-scale study done; P levels less than 1 mg/L without chemical addition
Bolton Conv. Secondary 0.5	Alum	Lake Ontario 1975	Aeration Tank Effluent	80	6,241.08	No operational problems
Bowmanville Trickling Filter 0.5	-	Lake Ontario 1975	-	-	948.66	Partial full-scale study done
Brantford Conv. Secondary 12.5	Ferric chloride	Lake Erie 1973	Aeration Tank Outlet	10	14,592.93	No differences with either chemical; ferric chloride chosen
	Ferrous sulphate		Return Sludge	10	11,599.93	
Brockville Primary 3.75	Alum	Lake Ontario 1975	Aerated Grit Tank	60	16,570.08	
Burlington - Skway Extended Aeration 6.0	Alum	Lake Ontario 1975	Aeration Tank Effluent	72	27,650.38	Recommend ferric salt; either ferric sulphate or ferric chloride
	Ferric sulphate		Aeration Tank Effluent	7.2		
Burlington - Drury Lane Conv. Secondary 2.5	Ferric chloride	Lake Ontario 1975	Aeration Tank	9.0	11,924.24	No operational problems

APPENDIX II. (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	CHEMICAL TESTED	RECEIVING BASIN IMPLEMENTATION DATE	POINT OF ADDITION	REQUIRED DOSAGE TO MEET OBJECTIVES (mg/L)	FULL-SCALE TESTING COST ($)	COMMENTS
Caledonia Conv. Secondary 0.5	Lime	Lake Erie 1973	Grit Channel Effluent	180-200	12,023.15	High dosages resulted in build-up of deposits
Campbellford Conv. Secondary 0.75	No chemical necessary	Lake Ontario 1973	-	-	0	No full-scale study done; P levels less than 1 mg/L without chemical addition
Cayuga Oxidation Ditch 0.20	Ferric chloride	Lake Erie 1973	Oxidation Ditch Outlet	12.5	8,908.60	No operational problems
Chatham Conv. Secondary 4.5	Ferrous sulphate	Lake Erie 1973	Raw Sewage	20	0	COA report
Cobourg Conv. Secondary 3.53	-	Lake Ontario 1975	-	-	6,443.07	Partial full-scale study done; P concentrations less than 1 mg/L without chemical addition
Cornwall Primary 8.0	-	Lake Ontario 1975	-	-	0	No full-scale study done
Delhi Conv. Secondary 0.5	Ferric chloride	Lake Erie 1973	Aeration Tank	5.5	9,379.88	
Dundalk Lagoon 16 Acres	Alum	Lake Erie 1973	Batch Treatment	-	-	

APPENDIX II. (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	CHEMICAL TESTED	RECEIVING BASIN IMPLEMENTATION DATE	POINT OF ADDITION	REQUIRED DOSAGE TO MEET OBJECTIVES (mg/L)	FULL-SCALE TESTING COST ($)	COMMENTS
Dundas Conv. Secondary 2.0	Alum	Lake Ontario 1975	Aeration Tank Effluent	60	14,005.19	No operational problems
Dunnville Conv. Secondary 1.7	Pickle liquor	Lake Erie 1973	Aeration Tank	6-7	13,938.33	Ferric chloride used as standby chemical
Dutton Lagoon 10 Acres	Alum	Lake Erie 1973	Batch Treatment	-	0	No full-scale testing done
Elmira Conv. Secondary 0.68	Ferric chloride	Lake Erie 1973	Aeration Tank	7.0	9,260.00	Effluent high in suspended solids; recommend tests with polyelectrolytes
Elora Extended Aeration 0.1	Ferric chloride	Lake Erie 1973	Raw Sewage	15.0	10,158.64	Flocculant addition discontinued; no operational problems
Essex Lagoon 10 Acres	Alum	Lake Erie 1973	Batch Treatment	-	0	No full-scale study done
Fergus Conv. Secondary 1.1	Ferric chloride	Lake Erie 1973	Aeration Tank Effluent	9.5	11,108.62	No operational difficulties
Fort Erie Primary 1.8	Ferric chloride	Lake Ontario 1975	Grit Chamber Overflow	14	10,406.31	No operating problems

APPENDIX II. (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	CHEMICAL TESTED	RECEIVING BASIN IMPLEMENTATION DATE	POINT OF ADDITION	REQUIRED DOSAGE TO MEET OBJECTIVES (mg/L)	FULL-SCALE TESTING COST ($)	COMMENTS
Fort Erie - Crystal Beach Conv. Secondary 0.85	Alum	Lake Erie 1973	Grit Tank Inlet	25	7,477.84	
Frankford Conv. Secondary 0.30	Dry Alum	Lake Ontario 1973	-	-	0	No full-scale study done
Galt Conv. Secondary 8.5	Ferric chloride	Lake Erie 1973	Aeration Tank Effluent	16	10,340.95	
Georgetown Conv. Secondary 1.5	"	Lake Ontario 1975	-	-	0	No full-scale study done
Grand Valley Oxidation Ditch 0.13	Dry Alum	Lake Erie 1973	-	-	0	No full-scale study done
Guelph Conv. Secondary 10.0	Alum Activated Silica	Lake Erie 1973	Aeration Tank Effluent	100 4	10,454.40	No operational problems
Hagersville Conv. Secondary 0.20	Alum	Lake Erie 1973	Aeration Tank Effluent	75	1,249.55	Plant hydraulically overloaded-sewage sometimes bypassed
Hamilton Conv. Secondary 60.0	"	Lake Ontario 1975	-	-	0	No full-scale study done; P levels less than 1 mg/L without chemical addition

APPENDIX II. (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	CHEMICAL TESTED	RECEIVING BASIN IMPLEMENTATION DATE	POINT OF ADDITION	REQUIRED DOSAGE TO MEET OBJECTIVES (mg/L)	FULL-SCALE TESTING COST ($)	COMMENTS
Hespler Conv. Secondary 1.6	Ferric chloride	Lake Erie 1973	Grit Removal Section Exit	7.0	6,925.48	No operational problems
Ingersoll Conv. Secondary 2.25	Alum	Lake Erie 1973	-	-	0	No full-scale study done
Jarvis Lagoon 14 Acres	Alum	Lake Erie 1973	Batch Treatment	-	0	No full-scale study done
Kingston Primary 13.5	-	Lake Ontario 1975	-	-	0	Recommend full-scale testing after permanent facilities installed
Kingston Twp. Conv. Secondary 2.2	-	Lake Ontario 1975	-	-	0	No full-scale study done
Kingsville Lagoon 43 Acres	Alum	Lake Erie 1973	Batch Treatment	150	8,081.37	
Kitchener Conv. Secondary 13.5	Alum	Lake Erie 1973	Aeration Tank Effluent	90	29,451.72	No operational problems
Lakefield Lagoon 24 Acres	Alum	Lake Ontario 1973	Batch Dosage	-	0	No full-scale study done

APPENDIX II. (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	CHEMICAL TESTED	RECEIVING BASIN IMPLEMENTATION DATE	POINT OF ADDITION	REQUIRED DOSAGE TO MEET OBJECTIVES (mg/L)	FULL-SCALE TESTING COST ($)	COMMENTS
Leamington Primary 2.0	Ferric chloride	Lake Erie 1973	Grit Collector Inlet or Raw Sewage Pump	15	22,824.90	Plant hydraulically overloaded; two canneries contribute waste at various times-expansion recommended
Lindsay Lagoon 111 Acres	Alum	Lake Ontario 1973	Raw Sewage Pump	150	0	No full-scale study done
London - Adelaide Conv. Secondary 2.0	Ferric chloride	Lake Erie 1973	Aeration Tank Effluent	21.68	19,476.77	Lime not suitable; switched to ferric chloride
London - Greenway Conv. Secondary 18.3	Ferric chloride	Lake Erie 1973	Aeration Tank Effluent	3.0	8,734.32	No operation difficulties
London - Oxford Conv. Secondary 1.2	Ferric chloride	Lake Erie 1973	Aeration Tank Effluent	45	14,316.74	Lime not suitable; switched to ferric chloride
London - Pottersburg Conv. Secondary 4.0	Ferric chloride	Lake Erie 1973	Aeration Tank Effluent	30	19,851.58	Switched to ferric chloride for economic reasons

APPENDIX II. (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	CHEMICAL TESTED	RECEIVING BASIN IMPLEMENTATION DATE	POINT OF ADDITION	REQUIRED DOSAGE TO MEET OBJECTIVES (mg/L)	FULL-SCALE TESTING COST ($)	COMMENTS
London - Vauxhall Conv. Secondary 3.5	Lime	Lake Erie 1973	Raw Sewage Ahead of Degrittor	160	16,960.49	Plant operation improved
Madoc Lagoon 30 Acres	Alum	Lake Ontario 1973	Batch Dosage	-	0	No full-scale study done
Markham - John Street Conv. Secondary 0.75	Ferric chloride	Lake Ontario 1975	Aeration Tank Effluent	9.5	12,411.26	No operational difficulties
Markham - Unionville Secondary & Lagoon 0.4	Ferric chloride	Lake Ontario 1975	Aeration Tank Effluent	11.0	11,702.32	No operational difficulties
Markham - Old Plant	-	Lake Ontario 1975	-	-	0	No full-scale study done
Napanee Primary 1.5	Alum Ferric chloride	Lake Ontario 1975	Raw Sewage	150 12		Full-scale study done by MOE Research Branch
New Hamburg Lagoon 7.5	Alum	Lake Erie 1973	-	-	0	No full-scale study done
Niagara Falls - Stamford Primary 10.0	Ferric chloride	Lake Ontario 1975	Raw Sewage	19	14,306.55	No operational problems

APPENDIX II. (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	CHEMICAL TESTED	RECEIVING BASIN IMPLEMENTATION DATE	POINT OF ADDITION	REQUIRED DOSAGE TO MEET OBJECTIVES (mg/L)	FULL-SCALE TESTING COST ($)	COMMENTS
Norwich Lagoon 15 Acres	Alum	Lake Erie 1973	-	-	0	No full-scale study done
Norwood Oxidation Ditch 0.15	Dry Alum	Lake Ontario 1973	-	-	0	No full-scale study done
Oakville - East End Conv. Secondary 2.0	Ferric chloride	Lake Ontario 1975	Aeration Tank Effluent	14	11,050.61	No operational problems
Milton Conv. Secondary 1.0	Lime	Lake Ontario 1975	Tertiary Section Influent	150	10,430.89	Lime at 150 does not produce 1.0 mg/L of P residual, may be due to inconsistent sludge return; 200 mg/L may produce required effluent level
Mississauga - Clarkson Extended Aeration 24.0	Ferric chloride	Lake Ontario 1975	Aeration Tank Effluent	12.0	23,116.98	No operational problems
Mississauga - Lakeview Conv. Secondary 37.5	Ferric chloride	Lake Ontario 1975	Aeration Tank Effluent	10	18,853.44	Feedback of filterable P-expected to cease when whole plant in operation
Mitchell Lagoon 67 Acres	Alum	Lake Erie 1973	Batch Treatment	-	0	No full-scale study done

APPENDIX II. (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	CHEMICAL TESTED	RECEIVING BASIN IMPLEMENTATION DATE	POINT OF ADDITION	REQUIRED DOSAGE TO MEET OBJECTIVES (mg/L)	FULL-SCALE TESTING COST ($)	COMMENTS
Moore Twp. - Corunna Conv. Secondary 0.32	Ferric chloride + Lime	Lake Erie 1973	Aeration Tank Effluent Aeration Tank Influent	25.4 + 51.0	9,998.46	Ferric chloride in final effluent implemented
Oakville - West End Conv. Secondary 6.5	Ferric chloride	Lake Ontario 1975	Aeration Tank Effluent	17	14,605.25	No operational problems
Orangeville Conv. Secondary 0.75	-	Lake Ontario 1975	-	-	0	No full-scale study done
Oshawa - Harmony Creek Trickling Filter 7.5	-	Lake Ontario 1975	-	-	1,272.18	Partial full-scale study done
Oshawa # 2 Primary 5.0	-	Lake Ontario 1975	-	-	0	No full-scale study done
Paris Extended Aeration 0.5	Alum	Lake Erie 1973	Aeration Tank Effluent	75	7,841.19	No operational problems
Peterborough Primary 12.0	Ferric chloride	Lake Ontario 1973	Raw Sewage	10	14,647.95	No operational problems

APPENDIX II. (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	CHEMICAL TESTED	RECEIVING BASIN IMPLEMENTATION DATE	POINT OF ADDITION	REQUIRED DOSAGE TO MEET OBJECTIVES (mg/L)	FULL-SCALE TESTING COST ($)	COMMENTS
Petrolia Lagoon 32 Acres	Alum	Lake Erie 1973	Batch Treatment	-	0	No full-scale study done
Twp. of Pickering - Frenchman Bay Conv. Secondary 2.5	-	Lake Ontario 1975	-	-	2,926.19	Partial full-scale study done
Picton Contact Stabilization 1.0	Alum Ferric chloride	Lake Ontario 1975	Contact Zone Effluent	125 15	0	COA Research Report
Point Edward Primary 0.57	Alum Ferric chloride + Lime	Lake Erie 1973	Raw Sewage	120 25 + 120	0	COA Research Report
Port Colborne - East Conv. Secondary 0.85	Alum	Lake Ontario 1975	Aeration Tank	22	11,475.76	No operational problems
Port Colborne - West Conv. Secondary 0.9	Strong Sewage Ferric chloride Alum Weak Sewage Ferric chloride Alum	Lake Ontario 1975	Aeration Tank Effluent Grit Channel Effluent	 2 35 9 70	28,229.34	No operational problems

APPENDIX II. (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	CHEMICAL TESTED	RECEIVING BASIN IMPLEMENTATION DATE	POINT OF ADDITION	REQUIRED DOSAGE TO MEET OBJECTIVES (mg/L)	FULL-SCALE TESTING COST ($)	COMMENTS
Port Dover Primary 2.09	Ferric chloride	Lake Erie 1973	Grit Chamber	20	7,267.14	No operation difficulties
Port Hope Conv. Secondary 2.0	Alum (old plant) Alum (new plant)	Lake Ontario 1975	Aeration Influent Aeration Influent	30.66	14,450.63	No operational problems
Port Perry Lagoon 45 Acres	Alum	Lake Ontario 1973	Batch Dosage	-	0	No full-scale study done
Port Rowan Lagoon 21 Acres	Alum	Lake Erie 1973	Batch Treatment	-	0	No full-scale report done
Port Stanley Lagoon 40 Acres	Alum	Lake Erie 1973	Batch Treatment	-	0	No full-scale report done
Prescott Primary 1.0	-	Lake Ontario 1975	-	-	0	No full-scale study done
Preston Conv. Secondary 3.7	Ferric chloride	Lake Erie 1973	Aeration Tank Effluent	8	12,629.12	Dosage lower than expected
Richmond Hill Conv. Secondary 1.6	-	Lake Ontario 1975	-	-	0	No full-scale study done; plant under expansion

APPENDIX II. (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	CHEMICAL TESTED	RECEIVING BASIN IMPLEMENTATION DATE	POINT OF ADDITION	REQUIRED DOSAGE TO MEET OBJECTIVES (mg/L)	FULL-SCALE TESTING COST ($)	COMMENTS
Richmond Hill - North Don Conv. Secondary 1.4	Alum	Lake Ontario 1975	Aeration Tank	4.4	2,730.34	No operational problems
Ridgetown Lagoon 39.5 Acres	Alum	Lake Erie 1973	Batch Treatment	-	0	No full-scale report done
Sarnia Primary 8.0	Ferric chloride	Lake Erie 1973	Grit Tank Inlet	20	19,543.98	No operational problems
Sidney - Batawa Conv. Secondary 0.12	Alum	Lake Ontario 1973	Aeration Tank Effluent	20	1,713.96	No operational problems
Simcoe Conv. Secondary 2.0	Alum	Lake Erie 1973	Aeration Tank Effluent	106	11,661.66	No pre-test data on sludge volume given; suggest dewater sludge before digestion
St. Catharines - Port Dalhousie Primary 9.0	-	Lake Ontario 1975	-	-	0	No full-scale study done; plant under expansion
St. Catherines - Port Weller Conv. Secondary 8.2	Alum	Lake Ontario 1975	Aeration Tank Effluent	44	14,411.17	No operational problems

APPENDIX II. (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	CHEMICAL TESTED	RECEIVING BASIN IMPLEMENTATION DATE	POINT OF ADDITION	REQUIRED DOSAGE TO MEET OBJECTIVES (mg/L)	FULL-SCALE TESTING COST ($)	COMMENTS
St. Mary's Conv. Secondary 3.7	Ferric chloride	Lake Erie 1973	-	-	0	No full-scale study done
St. Thomas Conv. Secondary 3.6	Alum	Lake Erie 1973	Raw Sewage	83	17,996.91	Digestors may be over-loaded
Stirling Lagoon 12.6 Acres	Alum	Lake Ontario 1973	Batch Dosage	-	0	No full-scale study done
Stouffville Conv. Secondary + Tertiary 0.49	Ferric chloride	Lake Ontario 1975	Aeration Tank Effluent	7	11,066.42 (partial)	
Stratford Conv. Secondary + Tertiary 6.0	Ferric chloride	Lake Erie 1973	Aeration Tank Effluent	10	0	Report done on tertiary addition
Strathroy Lagoon 60 Acres	Alum	Lake Erie 1973	-	-	0	No full-scale study done
Tavistock Lagoon 30 Acres	Alum	Lake Erie 1973	-	-	0	No full-scale study done

APPENDIX II. (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	CHEMICAL TESTED	RECEIVING BASIN IMPLEMENTATION DATE	POINT OF ADDITION	REQUIRED DOSAGE TO MEET OBJECTIVES (mg/L)	FULL-SCALE TESTING COST ($)	COMMENTS
Tilbury Lagoon 36 Acres	Test 1 Alum (east pond)	Lake Erie 1973	Batch Treatment	175	Test 1 6,458.02	Results from Test 1 not satisfactory (algae bloom)
	Test 2 Alum (west pond)		Batch Treatment	150	Test 2 2,980.07	
Tillsonburg Conv. Secondary 1.8	Alum	Lake Erie 1973	Aeration Tank Effluent	138	10,217.08	No operational problems
Trenton Primary 1.0	-	Lake Ontario 1975	-	-	0	No full-scale study done
Metro Toronto - Humber Conv. Secondary 62.5	Ferric chloride	Lake Ontario 1975	Aeration Tank Effluent	6	20,105.13	Report to be submitted
Metro Toronto - Main Conv. Secondary 180.0	Ferric chloride	Lake Ontario 1975	Aeration Tank Effluent	12	11,877.29	Ferric chloride in use
Metro Toronto - Highland Creek Conv. Secondary 16.0	Ferric chloride	Lake Ontario 1975	Aeration Tank Effluent	16	6,050.30	Report to be submitted

APPENDIX II. (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	CHEMICAL TESTED	RECEIVING BASIN IMPLEMENTATION DATE	POINT OF ADDITION	REQUIRED DOSAGE TO MEET OBJECTIVES (mg/L)	FULL-SCALE TESTING COST ($)	COMMENTS
Metro Toronto - North Conv. Secondary 7.5	Ferric chloride	Lake Ontario 1975	Aeration Tank	15	83,301.01	Report to be submitted
Vaughan - West Don Conv. Secondary 0.33	Ferric chloride	Lake Ontario 1975	Raw Sewage	125	23,584.06	Report to be submitted
	Polymer		Raw Sewage	9		
	Ferric chloride		Aeration Tank Effluent	14		
Wallaceburg Conv. Secondary 1.5	Lime	Lake Erie 1973	Raw Sewage	210	6,544.82	
Waterford Lagoon 15 Acres	Alum	Lake Erie 1973	-	-	0	No full-scale study done
Waterloo Conv. Secondary 6.0	Ferric chloride	Lake Erie 1973	Aeration Tank Effluent	4.0	5,614.61	No operational problems
Welland Conv. Secondary 10.0	Alum	Lake Ontario 1975	Aeration Tank Effluent	30	10,469.55	

APPENDIX II. (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	CHEMICAL TESTED	RECEIVING BASIN IMPLEMENTATION DATE	POINT OF ADDITION	REQUIRED DOSAGE TO MEET OBJECTIVES (mg/L)	FULL-SCALE TESTING COST ($)	COMMENTS
West Lorne Lagoon 20 Acres	Alum	Lake Erie 1973	-	-	0	No full-scale study done
Westminster Twp. - Lambeth Conv. Secondary 0.25	Ferric chloride	Lake Erie 1973	Aeration Tank Effluent	9	5,282.96	Comparison with ferric sulphate showed no major differences
	Ferric sulphate		Aeration Tank Effluent	9	4,685.68	
Town of Whitby - Corbett Creek Conv. Secondary 3.0	-	Lake Ontario 1975	-	-	25.10	Full-scale study not carried out because of low P Levels in the raw sewage
Town of Whitby - Pringle Creek Conv. Secondary 3.25	Ferric chloride	Lake Ontario 1975	Plant 1 Return Activated Sludge	8	12,943.14	No operational problems
			Plant 2 Return Sludge & Primary Clarifier Mixing Point	8		
Windsor - Little River Conv. Secondary 4.0	Alum	Lake Erie 1973	Raw Sewage	150	Total for all reports 46,052.63	Alum to raw sewage has best P removal; plant expansion recommended

APPENDIX II. (CONT'D)

MUNICIPALITY TYPE OF PLANT DESIGN FLOW (Imgd)	CHEMICAL TESTED	RECEIVING BASIN IMPLEMENTATION DATE	POINT OF ADDITION	REQUIRED DOSAGE TO MEET OBJECTIVES (mg/L)	FULL-SCALE TESTING COST ($)	COMMENTS
Windsor - West End Primary 24.0	High Iron Alum + Polymer	Lake Erie 1973	Raw Sewage Pump	80 + 0.4	61,826.88	Plant efficiency increased using high iron alum
Woodstock Conv. Secondary 4.5	Ferric chloride	Lake Erie 1973	Aeration Tank Effluent	17	16,454.05	
Woolwich Twp. - St. Jacobs Conv. Secondary 0.211	Alum	Lake Erie 1973	Aeration Ditch Effluent	20-30	6,148.93	No operational problems

APPENDIX III

OPERATIONAL DATA AND COST SUMMARY

APPENDIX III

PROVINCE OF ONTARIO PHOSPHORUS REMOVAL PROGRAM - OPERATIONAL DATA AND COST SUMMARY

MUNICIPALITY	TYPE OF TREATMENT	CHEMICAL USED	DOSAGE (mg/L)	SLUDGE DISPOSAL METHOD*	CHEMICAL COST ($/Img)	CAPITAL COST OF PHOSPHORUS REMOVAL EQUIPMENT ($)
Amherstburg	Primary	Ferric chloride	20	l	41.88	25,000
Aurora	Secondary	None used	0	f	0	5,000
Muskoka - Bala	Primary	Lime	167	o	36.00	5,000
Barrie	Secondary	Alum	110-120	f	47.40	400,000
Bradford	Secondary	Alum	100-200	f,o	62.48	10,500
Brantford	Secondary	Ferrous sulphate	10-12	f,l	9.35	14,400
Cambridge - Galt	Secondary	Ferrous sulphate	2 1/2-3	f	2.48	16,500
- Hespeler	Secondary	Ferrous sulphate	4	f	3.60	10,000
- Preston	Secondary	Ferrous sulphate	7.5	f	6.75	9,500
Haldimand - Caledonia	Secondary	Lime	100	f	18.00	20,000
Cayuga	Secondary	Ferric chloride	2	f	3.50	11,000

*f - farm land
l - landfill
o - other
i - incineration

APPENDIX III. (CONT'D)

MUNICIPALITY	TYPE OF TREATMENT	CHEMICAL USED	DOSAGE (mg/L)	SLUDGE DISPOSAL METHOD*	CHEMICAL COST ($/Img)	CAPITAL COST OF PHOSPHORUS REMOVAL EQUIPMENT ($)
Chatham	Secondary	Ferrous sulphate	15-16	f	12.40	18,000
Collingwood	Primary	Ferric chloride	10	f	19.53	33,000
Delhi	Secondary	Alum	50-60	f	22.57	10,000
Dunnville	Secondary	Ferrous chloride	8.0	f	pickle liquor received from industry	65,000
Elora	Secondary	Ferric chloride	4.0-6.0	f	12.50	8,500
Fergus	Secondary	Ferrous sulphate	3-5	f	3.96	8,000
Fort Erie - Crystal B.	Secondary	Alum	1**	o	negligible	24,500
Frankford	Secondary	Ferric chloride	15	f	45.00	10,000
Grand Valley	Secondary	Ferric chloride	20.8	f	72.70	300
Gravenhurst	Secondary	Ferric chloride	10	o	20.97	15,000
Guelph	Secondary	Alum	60	f	22.70	40,000

*f - farm land
l - landfill
o - other
i - incineration

** Phosphorus values less than 1 mg/L without chemical addition.

APPENDIX III. (CONT'D)

MUNICIPALITY	TYPE OF TREATMENT	CHEMICAL USED	DOSAGE (mg/L)	SLUDGE DISPOSAL METHOD*	CHEMICAL COST ($/Img)	CAPITAL COST OF PHOSPHORUS REMOVAL EQUIPMENT ($)
Haldimand - Hagersville	Secondary	Ferric chloride	17	o	30.00	9,000
Huntsville	Secondary	Alum	140	f	56.82	10,000
Ingersoll	Secondary	Ferric chloride	8	f	15.00	8,500
Kemptville	Primary	Lime	175-200	o	41.16	20,000
Kitchener	Secondary	Ferrous sulphate	10	f	8.70	13,700
Leamington	Primary	Ferric chloride	15	l	29.25	N/A
London - Adelaide	Secondary	Ferric chloride	20	o	40.02	52,200
- Greenway	Secondary	None used		i	0	66,200
- Oxford	Secondary	Ferric chloride	15	i	30.02	53,000
- Pottersburg	Secondary	Ferric chloride	20	l	40.02	24,000
- Vauxhall	Secondary	Lime	40-60	o	8.63	55,700
Midland	Primary	Lime	200	f	44.35	8,000

*f - farm land
l - landfill
o - other
i - incineration

APPENDIX III. (CONT'D)

MUNICIPALITY	TYPE OF TREATMENT	CHEMICAL USED	DOSAGE (mg/L)	SLUDGE DISPOSAL METHOD*	CHEMICAL COST ($/Img)	CAPITAL COST OF PHOSPHORUS REMOVAL EQUIPMENT ($)
Moore Twp.	Secondary	Ferric chloride	16	o	30.48	8,500
Mount Forest	Secondary	Ferrous sulphate	N/A	f	N/A	6,900
Nanticoke - Port Dover	Primary	Ferric chloride	6.3	f	10.32	10,000
Newmarket	Secondary	Ferric chloride	10	f,l	17.79	90,000
North Bay	Secondary	Ferric chloride	6	o	7.20	15,000
Orangeville	Secondary	Alum	60	f	24.88	32,000
Orillia	Secondary	Alum	50-65	o	23.33	38,000
Owen Sound	Primary	Ferric chloride	13	f	24.30	15,000
Pt. Edward	Primary	Ferric chloride	19	o	34.96	9,000
Paris	Secondary	Ferric chloride	2	l	3.74	13,500
Parry Sound	Primary	Alum	100	f,o	41.24	10,000
Penetanguishene	Secondary	Alum	33	f	14.70	10,000
Peterborough	Secondary	Ferric chloride	4.2	f	8.54	30,000

*f - farm land
l - landfill
o - other
i - incineration

APPENDIX III. (CONT'D)

MUNICIPALITY	TYPE OF TREATMENT	CHEMICAL USED	DOSAGE (mg/L)	SLUDGE DISPOSAL METHOD*	CHEMICAL COST ($/Img)	CAPITAL COST OF PHOSPHORUS REMOVAL EQUIPMENT ($)
St. Mary's	Secondary	Ferric chloride	9	f	15.26	8,500
St. Thomas	Secondary	Alum	50	f,o	21.20	30,000
Sarnia	Primary	Ferric chloride	10-12	o	22.28	8,500
Sidney Twp. - Batawa	Secondary	Alum	30-35	f	13.33	1,000
Simcoe	Secondary	Ferrous sulphate	12-15	o	38.48	11,000
Smith Falls	Primary	Ferric chloride	30	f	54.00	25,000
Stratford	Secondary	Ferrous sulphate	8	f	7.29	9,500
Sturgeon Falls	Secondary	Alum	21	o	9.16	10,000
Tillsonburg	Secondary	Alum	50-60	f	22.57	8,500
Uxbridge	Secondary	Ferric chloride	15	f	29.66	11,000
Wallaceburg	Secondary	Ferrous sulphate	8-10	f	9.00	8,500
Waterloo	Secondary	Ferrous sulphate	5	f	4.25	8,000
Windsor - Little River	Secondary	Alum	65	o,l	23.06	225,000

*f - farm land
l - landfill
o - other
i - incineration

APPENDIX III. (CONT'D)

MUNICIPALITY	TYPE OF TREATMENT	CHEMICAL USED	DOSAGE (mg/L)	SLUDGE DISPOSAL METHOD*	CHEMICAL COST ($/Img)	CAPITAL COST OF PHOSPHORUS REMOVAL EQUIPMENT ($)
Windsor - Westerly	Primary	Ferric chloride	16	o,l	31.34	250,000
Westminster Twp. - Lambeth	Secondary	None used	0	f	0	10,500
Woodstock	Secondary	Ferric chloride	10	f	19.47	14,000
Woolwich Twp. - Elmira	Secondary	Ferrous sulphate	5	f	4.95	7,300
- St. Jacobs	Secondary	Alum	20-30	f	33.00	500

*f - farm land
l - landfill
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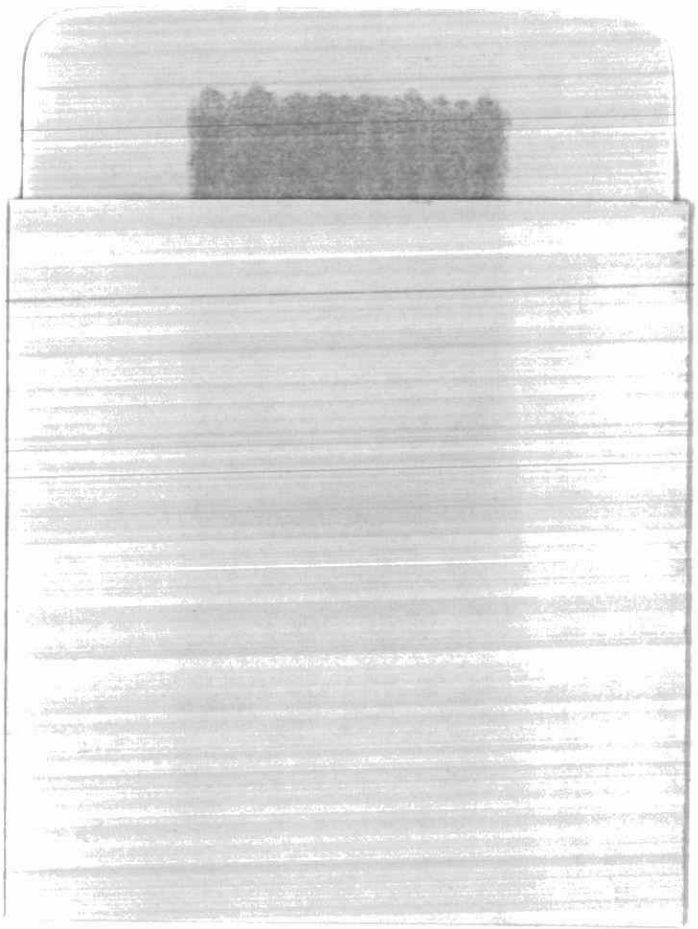
i - incineration



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